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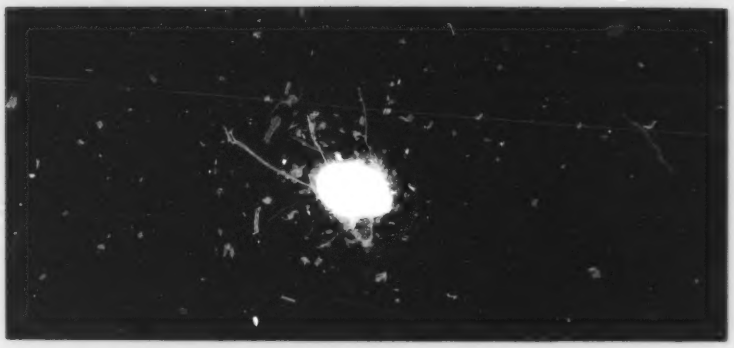

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# TP 11191E
# RUGGEDIZED TRANSDUCER SUBSYSTEM FOR ICE HAZARD DETECTION SONAR

for
Transportation Development Centre
Policy and Coordination Group
Transport Canada
July 1991

by

C-TECH LTD.

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16. Abstract

The design of an experimental ruggedized transducer subsystem to be fitted to an existing exploratory ice detecting sonar system mounted in the hull of a typical icebreaking freighter was undertaken in August 1988. The program also entailed fitting data collection interfaces for use in a subsequent field trial.

The implementation selected for this experimental system uses a dual proximity sounder fitted with forward and downward looking transducers to sense potentially hazardous ice fragments in the near field and activate a fast retraction of the system transducer in the event of a threat.

The proximity transceivers and alarm signal processor were developed to cope with the reverberation limited near field environment and allow a practical compromise with respect to transducer impact protection.

A hydraulically actuated retraction mechanism was designed to provide the feast retraction required at maximum ship's speed. It was found that considerable system design work may be required to custom fit the equipment to a specific ship.

The major elements of the design of an experimental system are complete, along with construction of many of the necessary electronic components. The next step would naturally involve the construction and testing of a final equipment for a specific platform.

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16. Résumé C'est en août 1988 qu'ont commencé les travaux de conception d'un sous-ensemble acoustique expérimental robuste devant être monté au-dessous du sonar expérimental existant placé au fond de la coque d'un cargo brise-glace. Il a fallu aussi prévoir la mise en place d'interfaces pour la saisie de données à l'occasion d'essais en mer à venir.

Le sous-ensemble retenu aux fins d'expérimentations comporte un sondeur de proximité double, formé d'un transducteur à axe dirigé vers l'avant et d'un autre axe dirigé vers le bas, et dont le but est de détecter la présence de dangereux fragments d'escamotage rapide du sonar principal.

Tant le sondeur de proximité que le processeur de signaux d'alarme sont conçus pour fonctionner dans un environnement acoustique assujetti à de fortes réverbérations. Le tout est le résultat d'un compromis prenant en compte la nécessité de protéger le sonar contre les impacts.

Un mécanisme hydraulique conçu exprès assure l'escamotage rapide du sonar principal même lorsque le navire avance à plein régime. Il faudra faire une étude serrée pour arriver à faire entrer ce mécanisme dans l'espace disponible s'il est très exigu. Le système expérimental est maintenant complètement dimensionné dans ses grandes lignes, et la plupart des principaux composants électroniques ont été réalisés. L'étape suivante de la recherche consistera à réaliser la version définitive du système en fonction de l'espace qui lui est réservé.


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Lloyd's Register of Shipping, Montreal; for their cooperation in providing access to personnel familiar with the applicable underwriters' regulations.

## SUMMARY

Navigation in ice infested Arctic waters could benefit from sensor technologies providing adequate information on icebergs in open and ice covered waters to allow optimum course selection and/or collision avoidance manoeuvres. The potential role of sonar sensors for assessment of the underwater ice hazard appears to warrant further investigation based on promise shown in prior work on acoustic detection of icebergs (see Refs. 1 and 2). Existing sonar systems are not well adapted for this service, particularly with respect to survivability. The logical next step appears to be development of a ruggedized, ice hardened system.

The design of an experimental ruggedized transducer subsystem to be fitted to an existing exploratory sonar system mounted in the hull of a typical icebreaking freighter, such as Canarctic Shipping Company's M.V. Arctic, was undertaken in August 1988. The program also entailed fitting data collection interfaces for use in a subsequent field trial. The collected data is required to assess the near and far field acoustic environment as well as the detection capabilities and survivability of the combined system comprising the ruggedized transducer subsystem coupled with the primary sonar, a modified and specially calibrated C-Tech CDS-40A 36 kHz sonar.

The implementation selected for this experimental system uses a dual proximity sounder fitted with forward and downward looking transducers to sense potentially hazardous ice fragments in the near field and activate a fast retraction of the system transducer in the event of a threat. Appropriate retraction response and latency times are determined from speed log input data. If the downward sensing sounder subsequently senses no obstruction, the transducer is slightly extended to a relatively protected low exposure peek mode to allow the forward sensing sounder to assess near field threat before fully extending again.

A modified C-Tech model FFC-2000 scrolling chart colour sounder display unit provides visual display of the near field ice flux and serves as a platform for the data collection interfaces and operator controls.

A multichannel instrumentation tape recorder and a data analyzer are expected to be used during the field trial data gathering phase.

The proximity transceivers and alarm signal processor were developed to cope with the reverberation limited near field environment; swept frequency pulse compression, reference image subtraction and multiple echo correlation techniques were incorporated.

A portable digital fibre optic cable link was developed to provide the additional communications required between operations area equipment and sonar compartment electronics without compromising the ship's intrinsic safety requirements when operating as a tanker. The cable's inherent interference resistance maintains the required data integrity. Existing sonar cabling and interfaces remain unaffected.

A hydraulically actuated retraction mechanism was designed to provide the fast retraction required at maximum ship's speed. A practical detection range for a 1 kg ice chunk was estimated as 20 m in the reverberation limited environment; this mass presents a practical compromise with respect to transducer impact protection.

The retraction system comprises a controller unit, retraction mechanism, hydraulic power unit, hydraulic valve block, sea chest, and air supply. A considerable amount of customized design was executed to fit such a system within the restricted cellular compartments available within a ship such as the M.V. Arctic without compromising the ship's structural integrity. As part of the work, compatibility with Lloyd's Register underwriters regulations was investigated.

The major elements of the design of an experimental system are complete, along with construction of much of the necessary electronic components.

The next step would naturally involve the construction of final equipment for a specific platform (such as the M.V. Arctic). This equipment will require extensive laboratory tests to prove the design approach prior to actual field trials on a ship in ice infested water.

1. "A Study Determining the Target Strength of Glacial Ice as a Function of Acoustic Frequency"; Report No. 813; March 1985; C-Tech Ltd., 525 Boundary Road, Cornwall, Ontario K6H 6N7.

2. "Close Range Acoustic Ice Hazard Detection, Phase II, Volume I, Final Report"; Canadian Astronautics Limited, 1050 Morrison Drive, Ottawa, Ontario K2H 8K7; P. de Heering and P. Sutcliffe.

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La navigation dans des eaux chargées de glaces gagnerait en sécurité si elle faisait appel aux nouveaux types de capteurs capables de détecter la présence d'icebergs flottant en eau libre ou pris dans les glaces. La sécurité accrue viendrait de la possibilité soit de choisir un itinéraire plus sûr, soit d'entreprendre à temps les manoeuvres d'évitement nécessaires. A la lumière des résultats prometteurs obtenus de deux études antérieures sur la détection acoustique des icebergs, voir les références 1 et 2, il semble utile d'étendre la recherche au rôle que pourraient jouer les capteurs sonars dans la détection de glaces entre deux eaux. Les sonars actuels ne conviennent pas à cet usage, surtout parce qu'ils résistent mal aux très dures conditions d'exploitation. La logique veut que l'étape suivante soit la mise au point d'un sonar robuste, renforcé contre l'action des glaces.

C'est en août 1988 qu'ont commencé les travaux de conception d'un sous-ensemble acoustique expérimental robuste devant être monté au-dessous du sonar expérimental existant placé au fond de la coque d'un cargo brise-glace type comme le N.M. Arctic appartenant à la Canarctic Shipping Company. Il a fallu aussi prévoir la mise en place d'interfaces pour la saisie de données à l'occasion d'essais en mer à venir. Ces données sont nécessaires à la mesure du champ acoustique proche et lointain et à l'évaluation des performances et de la tenue en service du système sonar combiné, qui comprend le sous-ensemble acoustique robuste monté au-dessous d'un sonar de pêche C-Tech CDS-40A de 30 kHZ modifié et soigneusement étalonné.

Le sous-ensemble retenu aux fins d'expérimentations comporte un sondeur de proximité double, formé d'un transducteur à axe dirigé vers l'avant et d'un autre à axe dirigé vers le bas, et dont le but est de détecter la présence de dangereux fragments de glace à proximité, auquel cas il actionne le mécanisme d'escamotage rapide du sonar principal. Les temps appropriés pour l'escamotage du sonar et pour le réarmorçage du mécanisme hydraulique sont déterminés en fonction de la vitesse du navire. Lorsque le transducteur à axe vertical cesse de détecter la présence d'obstacles, le sondeur émerge jusqu'à une certaine distance de sécurité, qui permet au transducteur frontal de vérifier l'absence ou la présence d'obstacles à proximité, auquel cas il autorise ou non la sortie complète du sonar principal.

Une unité cartographique couleur à défilement de marque C-Tech modèle FFC-2000 modifiée permet de visualiser le contenu du champ proche, tout en servant de support aux interfaces de saisie de données et aux commandes.

Il est possible qu'un magnétophone à canaux multiples ainsi qu'un analyseur de données soient utilisés durant la phase de saisie de données.

Tant le sondeur de proximité que le processeur de signaux d'alarme sont conçus pour fonctionner dans un environnement acoustique assujetti à de fortes réverbérations. Des techniques spéciales sont utilisées à cet effet : compression des impulsions et balayage en fréquence, soustraction des images de référence et corrélation des échos multiples.

Un câble numérique amovible à fibres optiques étudié exprès sert de liaison supplémentaire entre le compartiment où se trouvent les commandes et le compartiment électronique sans compromettre les caractéristiques de sécurité inhérentes au navire lorsqu'il est exploité comme navire-citerne. L'immunité du câble aux parasites permet de conserver l'intégrité des données qu'il véhicule. Le câble et les interfaces sonar existants ne sont pas touchés par cette installation.

Un mécanisme hydraulique conçu exprès assure l'escamotage rapide du sonar principal même lorsque le navire avance à plein régime. La portée que doit avoir le système pour pouvoir détecter un fragment de glace d'un kilo a été estimée à 20 m, eu égard aux nombreuses réverbérations. Cette masse est le résultat d'un compromis prenant en compte la nécessité de protéger le sonar contre les impacts.

Le mécanisme d'escamotage comprend une unité de commande, le mécanisme proprement dit, la pompe hydraulique, un distributeur, une caisse de prise d'eau et une alimentation d'air. Il a fallu faire une étude serrée pour arriver à faire tenir ce mécanisme dans l'espace très exigu qu'il a été possible de trouver au fond de l'Arctic, sans compromettre l'intégrité structurelle du navire. La recherche a, par ailleurs, approfondi cette question à la lumière des règlements imposés par la Lloyd's.

Le système expérimental est maintenant complètement dimensionné dans ses grandes lignes, et la plupart des principaux composants électroniques ont été réalisés.

L'étape suivante de la recherche consistera à réaliser la version définitive du système en fonction du support qui lui est réservé, en l'occurrence le cargo brise-glace Arctic, et à l'éprouver d'abord par de rigoureux essais en laboratoire et ensuite par des expérimentations destinées à en vérifier les performances en service.

Références

1. A study determining the target strength of glacial ice as a function of acoustic frequency, rapport n° 813, mars 1985, C-Tech Ltd., Cornwall (Ontario) K6H 6N7.

2. Close range acoustic ice hazard detection, phase II, volume I, rapport final par P. de Heering et P. Sutcliffe, Canadian Astronautics Limited, Ottawa (Ontario) K2H 8K7.

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## 1. INTRODUCTION

Navigation in ice infested Arctic waters could benefit from sensor technologies providing adequate information on icebergs in open and ice covered waters to allow optimum course selection and/or collision avoidance manoeuvres. Ice maps produced by the Atmosphere and Environment Service provide valuable information to Arctic mariners, but do not provide the real time information required for tactical ice avoidance. Although shipborne radar has proven useful in detecting large ice masses with considerable above water structure, it does not assure reliable detection of hazardous ice under the adverse weather conditions common to Arctic waters. On the other hand, sonar, which offers considerable advantage for the detection of sea ice at short range, has the potential to be an invaluable aid to ships operating in northern waters.

Based on promise shown in prior TDC sponsored work on acoustic detection of icebergs (see Ref 7.1 and 7.2), the potential role of sonar sensors for assessment of the underwater ice hazard warranted further investigation. Previous program stages were managed by Canarctic Shipping Company Limited, and concentrated on determining the feasibility of detecting sea ice formations and icebergs.

C-Tech Ltd. was contracted to supply and install a modified and specially calibrated version of one of its off-the-shelf commercial application CDS-40A 36 kHz sonars as an experimental and data gathering first phase exercise. This active sonar system provides omnidirectional azimuth coverage, with a source level of approximately 216 dB re 1 $\mu$Pa at 1 m and a 750 Hz rotating azimuth receive beam. Phased array techniques allow vertical tilt adjustment of both transmit and receive beams. Presentation is via an amplitude coded colour display, with both standard polar Plan Position Indicator and rectangular "B Scan" range/bearing formats available. Range scaling is selectable from 125 m to 2000 m in five ranges. A VCR interface was fitted to allow recording of the selected display presentation; in addition, a precision steered audio beam mode was developed and fitted for data collection purposes. The system was custom calibrated and supplied with C-Tech Report No. 764, "Calibration Data, Canarctic CDS-40A", subsequently replaced by Report No. 851 after a transducer refit.

C-Tech also provided the at-sea sonar operational expertise to support testing, and an Ottawa based consulting firm performed the data acquisition and analysis work.

These tests were carried out on Canarctic's northern waters cargo ship, the M.V. Arctic, and identified that glacial and sea cover ice are detectable by sonar. Data accumulated suggested that reasonable range requirements could be met with a sonar system designed for the application (see Ref. 7.2).

C-Tech was also contracted by Canarctic Shipping to perform a related study to determine the acoustic target characteristics of glacial ice as a function of frequency. This work involved extensive acoustic measurements of a dimensionally and structurally controlled manufactured-to-application block of simulated glacial ice under controlled laboratory conditions at C-Tech Ltd.'s Underwater Test Facility, and resulted in the report cited as Reference 7.1.

However, existing sonar systems are not well adapted for this service, particularly with respect to survivability. Although it has been proven through the earlier TDC programs that icebergs in a free water environment are readily detected by conventional sonar, it has also been shown that operating the same sonar from a platform moving through surface cover ice is not feasible without protecting the acoustic transducer from damage by ice pieces.

The acoustic transducer by its very nature is a mechanically sensitive device and satisfactory operation is dependent upon coupling the electromechanical element to the water medium. It is important to provide an unobstructed field of view of the surveillance area. Unique to the Ice Hazard Detection application, the sonar transducer must operate and survive in an environment where potential impact with ice pieces is a reality. The transducer mounting arrangement or deployment system must protect the transducer by avoiding and/or resisting ice impacts. The protection scheme has to be devised to retain the sensitive performance characteristics of the transducer, permit a clear acoustic field of view while echo-ranging, and assure, with a high rate of probability, that the transducer will not be destroyed by the ice.

The logical next step appears to be development of a ruggedized, ice hardened system.

The design of an experimental ruggedized transducer subsystem to be fitted to an existing exploratory sonar system mounted in the hull of a typical icebreaking freighter, such as Canarctic Shipping Company's M.V. Arctic, was undertaken in August 1988. The program also entailed fitting data collection interfaces for use in a subsequent field trial. The collected data is required to assess the near and far field acoustic environment as well as the detection capabilities and survivability of the combined system comprising the ruggedized transducer subsystem coupled with the primary sonar.

## 2. DEVELOPMENT

The considerations relating to the selected system architecture were initially explored in CTL Report No. 1065, entitled "Requirements for a Ruggedized Transducer Subsystem for Ice Hazard Detection Sonar". This report provided a foundation for determining the system parameters as subsequently defined in CTL Report No. 1075, "System Design Specification for a Ruggedized Transducer Subsystem for Ice Hazard Detection Sonar"; CTL Report No. 1069, "Statement of Work - Retraction Mechanism Subsystem for Ice Hazard Detection Sonar"; and CTL Sketch No. A-1098, "Retraction Mechanism Controller for Ice Hazard Detection Sonar". These reports are included as Appendices B through E for reference.

The selected "Seek and Hide" concept is based on the conventional sonar hull unit design wherein a mechanical hoist lowers and raises the transducer through a cylindrical well tube conveniently located in the ship's hull. These tubes are generally 203 mm to 381 mm (8" to 15") in diameter, resulting in minimal hull modification for fitting. The location, although not arbitrary, is selected with some freedom, and the absolute location can be dictated by hull structure.

Instead of strengthening the transducer to withstand the ice stresses for fixed mounting, a control system is designed to withdraw the transducer from the water when potentially damaging ice is approaching it. The hull assembly is mounted at the bottom of the hull at a point where ice pieces are normally expected to impact only occasionally. A separate acoustic proximity sensor array is used to detect pieces of ice in the water approaching the sonar transducer. The proximity sensors employ high frequency acoustics to detect the approach of ice at short range. A control system will automatically retract the transducer into the protection of the hull when threatening ice is detected. The retraction mechanism is designed to react quickly to withdraw the sonar transducer in a timely fashion to avoid serious damage due to ice impact.

The hull unit is located at a position in the ship's hull where hydrodynamic flow and vessel draft minimize the flux of ice pieces when the ship is in the ice-breaking mode.

A summary of the essential design determinants is as follows:

i) Modification of the existing experimental sonar transducer for protection against impacts with ice fragments of 1 Kg mass at speeds of 18 Knots is reasonable and conservative. Further investigation into enhanced transducer ruggedizing techniques for a sonar designed specifically for this application could potentially result in significant reductions in the required retraction mechanism power demand.

ii) The proximity transducer beamwidth is determined by acceptable field-of-view and acoustic reverberation considerations. As a result, a practical detection range for the forward proximity transceiver for a 1 kg ice mass is ca. 20 m. A revised analysis of the Proximity Sounder detection statistics is included as Appendix A. In view of the experimental nature of the program, and the lack of hard data on the ice flux, noise and reverberation levels to be encountered, an array of detection enhancement techniques were required to provide acceptable performance consistent with the assumptions made.

iii) The threat detection range, in conjunction with the proximity transceiver alarm processor response time, sets the retraction mechanism speed and power requirements. To provide the required performance levels, a hydraulic retraction system was selected; and additional design expertise was provided by two professors of the Engineering Graphics Unit of the Department of Mechanical Engineering at Queen's University, Kingston.

## 2.1 Additional Considerations

A number of issues principally relating to installation specific concerns surfaced during the course of the project.
A considerable amount of customized design was executed to fit such a system within the restricted cellular compartments available within a ship such as the M.V. Arctic without compromising the ship's structural integrity.

As part of the work, compatibility with Lloyd's Register underwriters' regulations was also investigated. The ship operates as a tanker as well as an ore carrier, and any electrical installations or structural modifications in areas adjacent to Cargo Oil Tanks which could prejudice the intrinsic safety of the ship require their approval. In addition, operation of the existing exploratory sonar installation in its present location is allowed only when the ship is not operating as a tanker, as it is not an intrinsically safe explosion proof apparatus. All power to the equipment must be cut when operating in tanker mode.

### 2.1.1 Communications Link

As outlined in the original proposal, the system architecture was to use an existing sounder platform, complete with appropriate modifications and ancillary functions, to allow development to proceed with minimum cost and provide equipment within the desired time frame. This architecture was selected based on the experimental nature of the program, and was not intended to reflect future end-user equipment. The requirements for additional major connecting cable runs and the distance between units were set accordingly in the subsequent Requirements document.

Based on the selected system architecture, the requirement for ca. 250 m of interconnecting cables between the sounder transducers and proximity sounders was re-iterated in the System Design Specification and detailed in Sketch No. B-729, "Ice Hazard Detection Sonar Operations Area Installation Drawing".

In a subsequent meeting to discuss outstanding issues, Canarctic proved quite helpful in resolving a number of installation related issues.

However, they indicated that installation of the additional cabling could not be accommodated with the ship in operation, and, since no electrical cables could be run on the deck, this would force postponement of the project. Canarctic recommended that C-Tech consider alternative solutions to the problem.

After considering possible solutions which would still meet the defined project objectives, it was proposed to use an intrinsically safe optical fibre cable run on the ship's deck. However, as with all solutions envisaged, this significantly increased the scope of the engineering effort as we were required to re-partition the existing equipment design to locate a substantial portion of the electronics in the sonar compartment, and create additional hardware, both to properly format the necessary data for interchange, and to control the digital data link.

### 2.1.2 Sea Chest

During the course of the Retraction Mechanism design, it was discovered that the clearance between the transducer and the hull tube would introduce unacceptable pressure loss at the required retraction travel speed. Further complications would arise from water viscosity change due to thermal coupling to the Arctic waters through the ship's hull.

To minimize the pressure loss, two methods were investigated.

1) Fitting a tube on the side of the hull tube (near the top) to allow the displaced water to return to the sea, a short distance away from the transducer.

2) Fitting a sea chest, capable of containing the volume of water displaced, directly on to the hull tube.

Method (1) was an undesired solution for Canarctic since it required an additional hull penetration, and was therefore left as a last recourse. Based on method (2), a sea chest was designed to fit a sub-compartment within the Sonar Compartment of the MV Arctic. Unfortunately, during a ship inspection shortly after design completion, it was discovered that a stiffening gusset was present within the area designated for the sea chest. At the time, the structural change posed by removal of the gusset was considered unacceptable by Canarctic and C-Tech was requested to redesign the sea chest to accommodate the gusset; this new design was subject to approval by Lloyd's Register through Canarctic.

### 2.1.3 Air Supply System

This unit was designed and specified to be part of a subsystem working in conjunction with the sea chest. The subsystem was necessary to cushion and regulate the volume of sea water displaced by the transducer travel within the hull tube. When the transducer is being extended, the air supply forces out the sea water within the sea chest; when the transducer is being retracted, the cushion of air provides sufficient space for the displaced sea water without excessive pressure build-up.

The Air Receivers (part of the Air Supply System) were designed to fit in a compartment next to the sea chest and the Air Compressor with its related controls was designed to fit shelves in the compartment above.

### 2.1.4 Hydraulic Power Unit and Valve Block

The Hydraulic Power Unit was designed based on a requirement for remote mounting imposed by space restrictions. The location originally recommended by Canarctic was approximately 12 m up and 30 m forward from the retraction mechanism. During an inspection of the ship, a more suitable but still not ideal alternate location approximately 11 m up from the retraction mechanism was recommended by C-Tech.

The remote location added to the power requirement and tank size. Further, because of the ambient temperature range encountered in Arctic service, and because of the cycling frequency, a heater as well as a cooling unit was required.

The high powered electric motor consequently required for the Hydraulic Power Unit was a special unit purchased in England by the power unit subcontractor.

In addition, the hydraulic valve block is to be designed to fit in a confined area, on a shelf in a compartment next to the retraction mechanism. This eliminates the possibility of using off-the-shelf items to assemble the required valve block combination.

### 2.1.5 Retraction Mechanism

The Retraction Mechanism design had to allow assembly in confined areas, such as the sonar compartment of the MV Arctic. The design of the lifting column allows the hydraulic cylinder to be pulled out while still attached to the hydraulic hoses, and the carriage holding it will also serve as a lifting member for the transducer shaft support.

The bushing and seal assembly is mounted on a dedicated flange to facilitate transducer replacement, since the overhead space in the MV Arctic does not allow removal of the retraction mechanism with the transducer attached.

## 3. IMPLEMENTATION

A system block diagram, which includes the primary sonar for reference, is presented in Figure 1.

The implementation selected for the experimental transducer subsystem uses a dual proximity sounder fitted with forward and downward looking transducers to sense potentially hazardous ice fragments. The forward looking transducer senses ice flowing along the ship's hull from the bow and activates a fast retraction of the system transducer in the event of a threat. Appropriate retraction response and latency times are determined from speed log input data. The downward looking transducer is used to sense ice below the transducer assembly, especially prior to projecting the transducer through the hull into the water below the ship. If the downward looking sounder senses no obstruction, the transducer is slightly extended to a relatively protected low exposure peek mode to allow the forward sensing sounder to assess near field threat before fully extending again.

A modified scrolling chart colour sounder display unit provides visual display of the near field ice flux and serves as a platform for the data collection interfaces and operator controls.

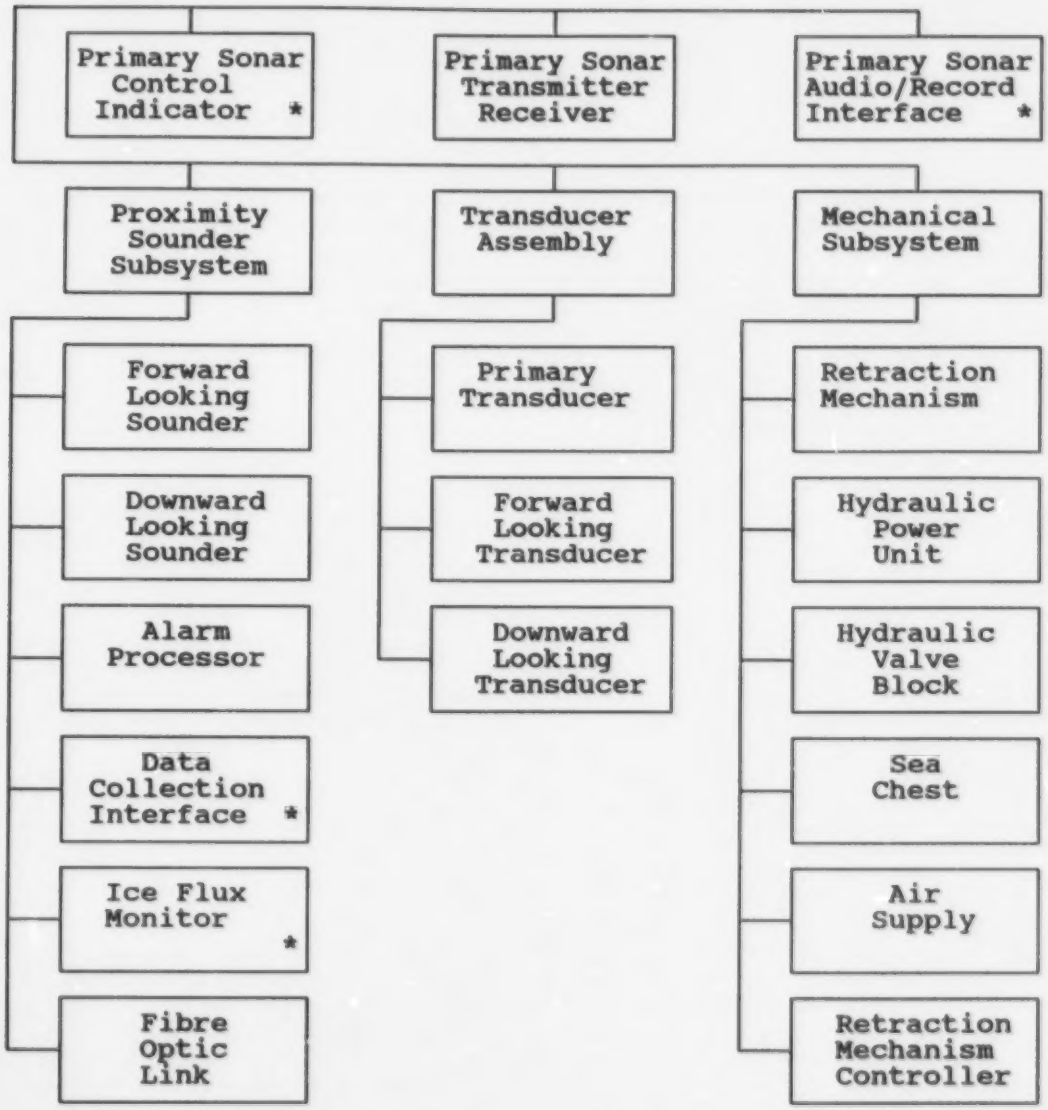
A multichannel instrumentation tape recorder and a data analyzer are expected to be used during the field trial data gathering phase.

The proximity transceivers and alarm signal processor were developed to cope with the reverberation limited near field environment; swept frequency pulse compression, own Doppler shift correction, reference image subtraction and multiple echo correlation techniques were incorporated.

A portable digital fibre optic cable link was developed to provide the additional communications required between operations area equipment and sonar compartment electronics without compromising the ship's intrinsic safety requirements when operating as a tanker. The cable's inherent interference resistance maintains the required data integrity. Existing sonar cabling and interfaces remain unaffected.

A hydraulically actuated retraction mechanism was designed to provide the fast retraction required at maximum ship's speed. A practical detection range for a 1 kg ice chunk was estimated as 20 m in the reverberation limited environment; this mass presents a practical compromise with respect to transducer impact protection.

The retraction system comprises a controller unit, retraction mechanism, hydraulic power unit, hydraulic valve block, sea chest, and air supply.




Note 1: Items denoted by an asterisk (*) are located in an operations area on or near the ship's bridge; unmarked items are located as required in sonar compartments at or near the retraction mechanism hull penetration.

Figure 1. System Block Diagram

## 4. SPECIFICATIONS

### 4.1 Transducer Assembly

This assembly comprises three transducer units, and is ruggedized to withstand impact of ice fragments of up to 1 kg mass at a speed of 18 knots. The transducer shaft is also fitted with a frangible point to allow a clean shear in the event of a collision.

The assembly is extended into the water below the ship by the retraction mechanism when in use, and retracted within a tube above the ship's gate valve when not in use.

The primary transducer is a ruggedized azimuthal omnidirectional multielement array interfacing with the primary sonar to provide the principal long range detection capability.

The forward looking proximity sounder directional array is mounted in an isolated housing directly below the primary transducer and protected from damage by small ice fragments by steel rails and plastic sheeting.

The downward looking transducer is also mounted in this housing behind an acoustically transparent window.

### 4.2 Proximity Sounder Subsystem

The forward looking sounder operates at a frequency of 80 kHz; and,in conjunction with its transducer, produces a projected acoustic source level of 207 dB re 1 μPa at 1 m with a beamwidth of 25 degrees in the horizontal plane and 10 degrees in the vertical plane. A 5 degree depression angle is used to minimize the hull return. In conjunction with the alarm processor, its estimated detection range for the projected -32 dB target strength of a 1 kg ice chunk at 80 kHz (see Ref. 5.1) is 20 m. The downward looking sounder operates at a frequency of 205 kHz; and, in conjunction with its transducer, produces a projected acoustic source level of 197 dB re 1 μPa at 1 m with a beamwidth of 17 degrees in the fore/aft plane and 17 degrees in the athwart plane. An 8 degree forward tilt, limited by hull tube grazing when retracted, provides a small bias in the direction of maximum threat. In conjunction with the alarm processor, its estimated detection range for the projected -44 dB target strength of a 1 kg ice chunk at 205 kHz (see Ref. 5.1) is 7 m.

Acoustic spreading losses are compensated with time varied gain, and a ± 6 dB sensitivity adjustment is provided in each channel.

Both sounders operate with an average pulse repetition period of 71 ms.

4.2.1 Alarm Processor

In the forward looking sounder, an adaptive fixed echo suppression mechanism is used to counter hull reverberation. A frequency modulated pulse compression technique, in conjunction with own Doppler shift correction derived from the ship's speed log data, is used to extend the basic volume reverberation limited ranging capability.

In both sounders, multi-ping post processing provides improved detection statistics for minimum sized targets.

The enhanced forward looking detection probability is estimated at 99.5% with a mean time to a false alarm of 9.3 hours, based on 5 ranging cycles out of 8; or 96.2% with a mean time to a false alarm of 379 hours, based on 6 ranging cycles out of 8. These are derived from estimated base detection statistics of 90% probability of detection at a receiver operating characteristic curve detection index of 16.

The enhanced downward looking detection probability is estimated at 99.9% with a mean time to a false alarm of 33.4 hours, based on 3 ranging cycles out of 4. These are derived from estimated base detection statistics of 99% probability of detection at a receiver operating characteristic curve detection index of 36.

A detailed analysis of the detection statistics for both sounders is presented in Appendix A.

If the forward looking sounder detects a threat, ship's speed log input is used to determine the optimum distance at which to initiate a retraction, and the optimum delay time to the subsequent extension attempt in order to clear the threat. An automatic retraction, which can be overridden, is initiated in the event the ship is moving at less than about 0.5 knot or moving in reverse. A new extension attempt will automatically be initiated when the ship's forward speed is resumed.

### 4.2.2 Data Collection Interface

Interface ports are provided to allow monitoring and recording of relevant operational data including ship's speed; forward and downward looking sounder return signals, both raw and processed; retraction mechanism operational status; and main sonar return signals. Operational status indicators are provided for operator feedback.

### 4.2.3 Ice Flux Monitor

A scrolling chart colour CRT display unit and microprocessor based controller, normally part of the C-Tech model FFC-2000 dual frequency echo sounder, were modified to support the Ice Flux Monitor and related functions.

The sounder display unit provides a visual display of the near field ice flux in rectangular format; the x axis presenting a history profile, with the y axis representing the target range of acoustic return intensity colour coded target data. Return signals from either or both proximity sounders may be selected for presentation, and a history screen may be saved for later recall. In addition, an "A" scope mode presenting a range line with width and colour modulation proportional to acoustic return intensity is also selectable as an aid to target classification.

Range scaling is selectable, and may be phased to retain resolution at longer target ranges.

The main chassis also serves as the platform for the retraction mechanism and proximity transceiver data collection interfaces and operator controls.

## 4.3 Mechanical Subsystem

The mechanical subsystem is required to rapidly and accurately position and maintain the transducer in any one of five defined positions in response to system commands. Various positions described below are illustrated in Figures 2 through 6.

A default "Rest" position, fully retracted above the ship's gate valve, is assumed whenever the system is not in its operational mode.

A "Hide" position just below the gate valve is provided to allow the downward looking sounder to look from within the hull tube for obstructions blocking exit from the tube.

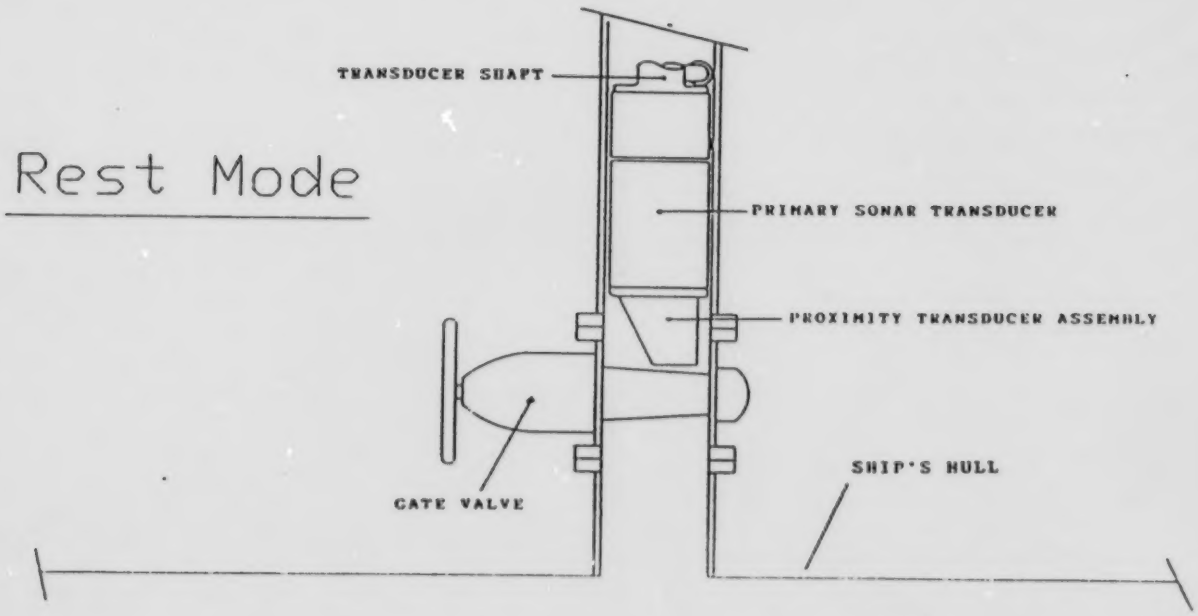



**Figure 2. Ruggedised Transducer Subsystem Operational Modes (Rest Mode).**

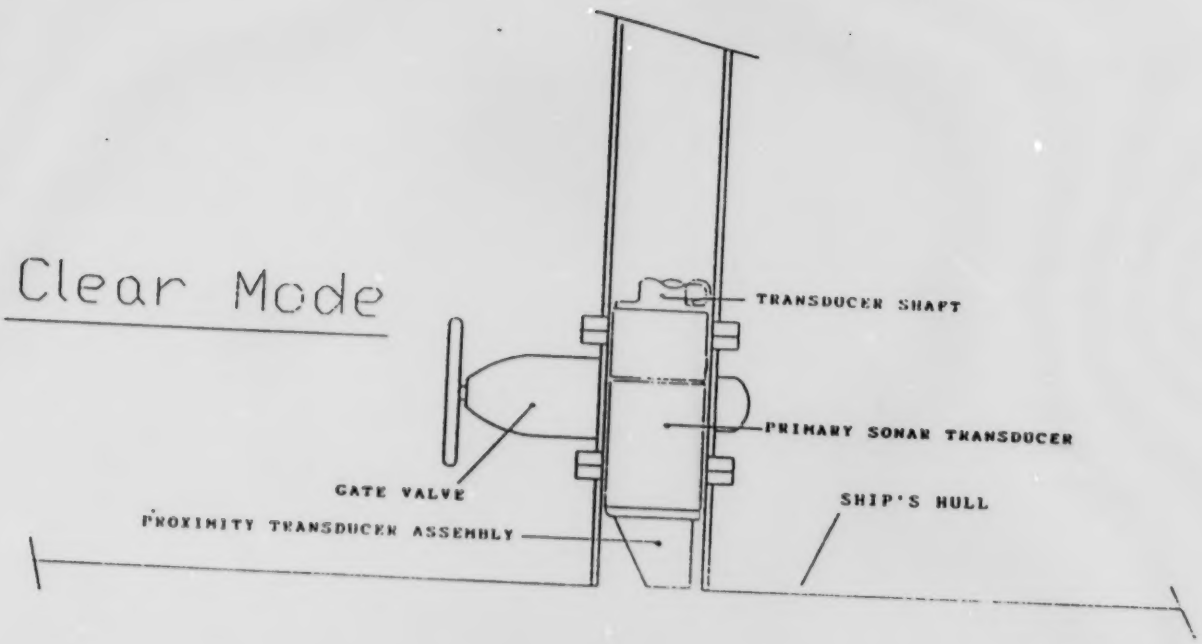



**Figure 3.** **Ruggedized Transducer Subsystem Operational Modes (Clear Mode).**

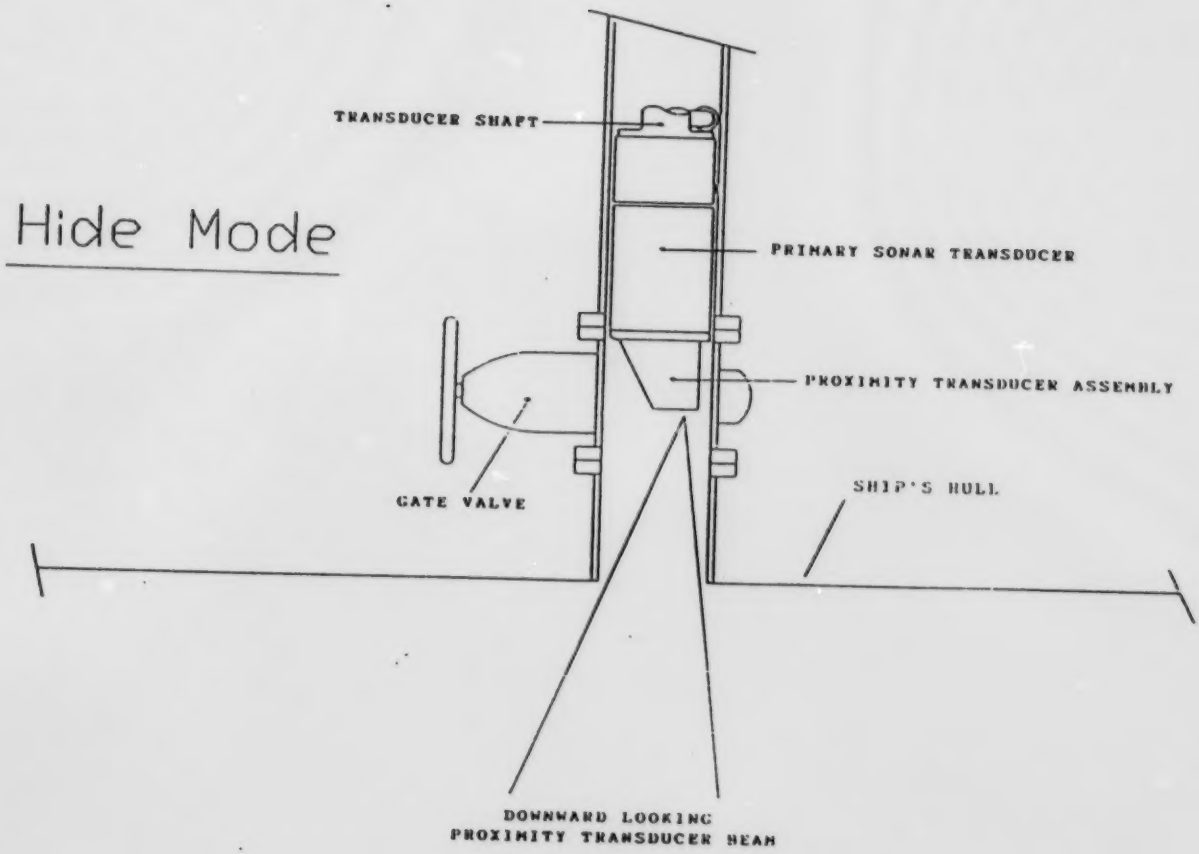



**Figure 4. Ruggedized Transducer Subsystem Operational Modes (Hide Mode).**

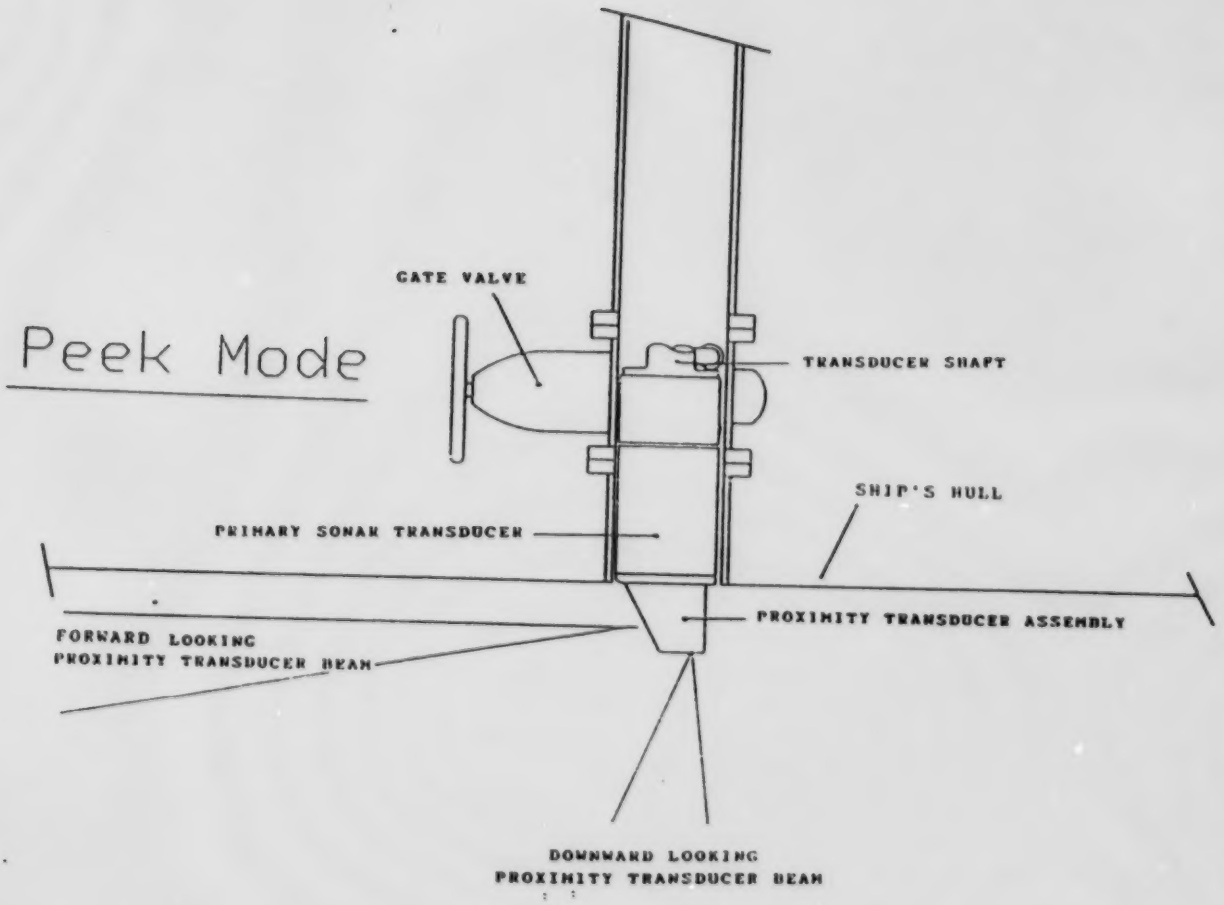



**Figure 5.** **Ruggedized Transducer Subsystem Operational Modes (Peek Mode).**

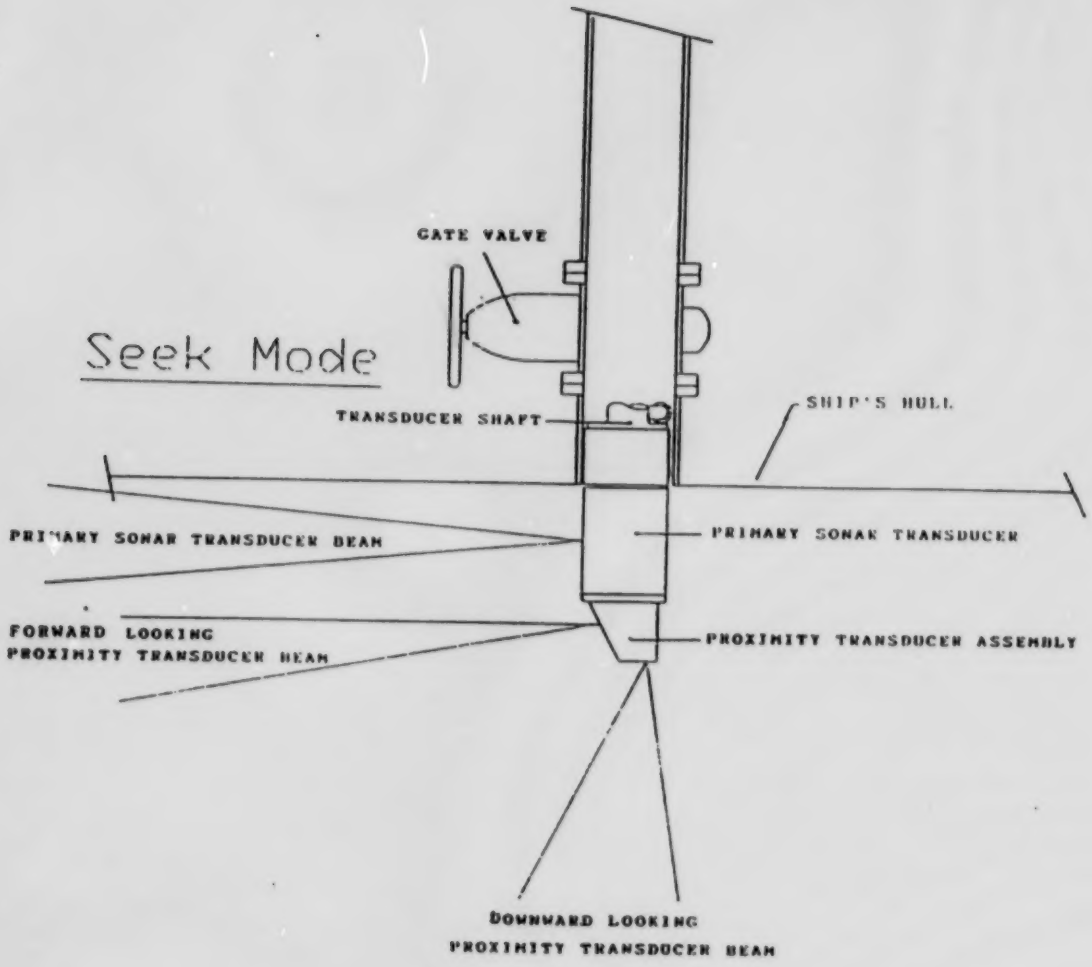



**Figure 6.** **Ruggedized Transducer Subsystem Operational Modes (Seek Mode).**

A "Clear" position, where the transducer descends to approximately 25 mm (1 in) above the mouth of the tube, is provided to allow the tube to be cleared of any ice debris which may have accumulated.

A "Peek" position, where the transducer assumes a slightly extended impact resistant position, is provided so its beam can graze along the hull to determine the presence of an immediate threat which would preclude a full extension.

A fully extended, fully operational "Seek" position is provided, in which the main sonar is functional and in which the proximity sounders provide maximum threat protection.

A hydraulic power unit supplies the motive power to operate the retraction mechanism, with solenoid valves controlling porting in a hydraulic valve block. Hydraulic fluid supplied from a high pressure pump charges an accumulator which rapidly accelerates the transducer shaft to approximately 1.5 m/s (60 in/s); a low pressure pump source is then used to maintain that speed for the remainder of its travel. Maximum stroke excursion is approximately 965 mm (38 in).

A sea chest is provided to allow for the rapid upward displacement of water trapped in the hull tube when the transducer is retracted.

An air supply fitted with water level sensing switches provides a controlled cushion of air within the sea chest, and expels the water when the transducer is extended.

### 4.3.1 Retraction Mechanism Controller

A functional specification has been prepared to define the requirements of the retraction mechanism controller. The controller reports status to, and accepts requests from, the alarm signal processor; and, in conjunction with feedback from a hoist position transducer, responds by rapidly and accurately positioning the retraction mechanism to the requested position via hydraulic control valves.

## 5. PROGRAM STATUS

The major elements of the design of an experimental system are complete, along with construction of many of the necessary electronic components. Appendix H provides, in summary form, the status of key events and Appendix I an estimated cost to complete the program. A list of documentation generated during the program is provided in Appendix F. As noted in Appendix F, a number of the drawings have been included in this report and others are available to the design authority on request.

It is unfortunate that the program could not be completed within the budgetary constraints. As discusssed earlier, a significant amount of additional design effort was necessitated due to the unanticipated events discussed in paragraphs 2.1.1 and 2.1.2.

We do feel however that the design approach taken is sound and has addressed all the major technical issues.

## 6. RECOMMENDATIONS

The next step would involve detailed design of the retraction mechanism controller and construction of a final equipment for a specific platform (such as the Canarctic Shipping Company Ltd. M.V. Arctic). In-house tests of the system would be followed by sea trials and a final report.

## 7. REFERENCES

"A Study Determining the Target Strength of Glacial Ice as a Function of Acoustic Frequency"; Report No. 813, March 1985; C-Tech Ltd., 525 Boundary Road, Cornwall, Ontario K6H 6N7.

"Close Range Acoustic Ice Hazard Detection, Phase II, Volume I, Final Report"; P. de Heering and P. Sutcliffe January 1987; Canadian Astronautics Limited, 1050 Morrison Drive, Ottawa, Ontario K2H 8K7.

"Principles of Underwater Sound", Third Edition; Robert J. Urick, 1983; McGraw-Hill Book Company, 1221 Avenue of the Americas, New York, NY 10020.

# APPENDIX A

## PROXIMITY SOUNDER DETECTION STATISTICS

# APPENDIX A

## 1. PROXIMITY SOUNDER DETECTION STATISTICS

An analysis of the proximity sounder detection statistics is presented hereunder.

### 1.1 Detection Statistics, Forward Channel

The echo excess (EE), the amount by which the echo exceeds the requirements set by the detection statistics, is given as follows:

$$EE = EL - RML$$

where the echo level (EL) is:

$$EL = SL - 2TL + TS$$

where SL = Source Level
TL = Transmission Loss
TS = Target Strength

and the reverberation masking level (RML) is:

$$RML = RL_s - 10 \log w' + 5 \log dw/t \text{ for } wt \gg 1$$

where the hull surface reverberation level ($RL_s$) is:

$$RL_s = SL - 3TL/2 + S_s + 10 \log ct/2 + [10 \log (b/2) - 12.6] \quad \text{(in dB)}$$

where $w'$ = Signal Bandwidth
$w$ = Receiver Bandwidth
$S_s$ = Surface Scattering Coefficient
$b$ = Beam Width
$d$ = Detection Index
$t$ = Pulse Length
$c$ = Sound Velocity

Assume suitable detection statistics for the fully extended mode:

$P_{(D)}$ = 90%, $P_{(FA)}$ = 1%, d = 16

where $P_{(D)}$ = Detection Probability
$P_{(FA)}$ = False Alarm Probability

For this case, figure 12.11 of reference 7.3 requires an additional 2 dB of echo level if wt = 11.

Hence, in that case,

$$RML = RL_s - 10 \log w' + 5 \log dw/t + 2$$

resulting in:

$$EE = -TL/2 + TS - S_s - 10 \log ct/2 - 10 \log b/2 + 10 \log w' - 5 \log dw/t + 12.6 - 2 \quad \text{(in dB)}$$

In the selected design,

w' = w = 4 kHz, t = 2.75 ms, d = 16
c = 1500 m/s, b = 25 degrees,

TL = 26 dB ref 1 m at 20 m range assuming spherical spreading and an absorption coefficient of 24 dB/km at 80 kHz,

TS = -32 dB based on reference 7.1 extended to a 0.01 $m^2$ ice target at a frequency of 80 kHz,

$S_s$ = -50 dB based on reference 7.3; the coefficient for a smooth hull surface is expected to be lower than that for a sandy bottom,

yielding:

EE = 0.4 dB

For the assumed value of $P_{(FA)}$, the probability of exactly x false alarms in the time t′ is given by the Poisson distribution:

$$P'_{(FA)} = e^{-\lambda}\lambda^x/x! \quad \text{where } \lambda = P_{(FA)}\, t'/t$$

To find t′ for $P'_{0(FA)} = 0.5$ where x = 0 (i.e. 0.5 probability of no false alarm),

$$e^{-\lambda} = 0.5 \text{ and } \lambda = 0.693 \text{ giving } t' = 381 \text{ ms.}$$

For a 30 m active period (r) and 71.1 ms pulse repetition rate ($T_r$), the receive duty cycle (D) where

$$D = [(2r/c)-t]/T_r = 0.524,$$

results in a mean time without false alarm of 727.5 ms. If the following assumptions are made with respect to dead time due to a false alarm induced retraction:

| Activity | Time (ms) |
|---|---|
| Seek to Hide mode | 1339 |
| 4 Downward Soundings | 284 |
| Hide to Peek mode | 843 |
| 8 Forward Soundings | 569 |
| Peek to Seek mode | 495 |
| Total | 3530 |

then an availability of 0.171 results.

### 1.1.1 Multiple Echo Correlation Post Processing

An m-out-of-n correlation post processor is used to improve $P'_{0(FA)}$ and system availability.

If m = 6 and n = 8 is considered for a 569 ms detection period, then, for the assumed design statistics, the cumulative binomial distribution:

$$P(m \geq 6) = P(6) + P(7) + P(8)$$

where $P(m) = \{n!/[m!(n-m)!]\}\pi^m(1-\pi)^{n-m}$ and $\pi = 0.9$,

results in a $P'_{(D)}$ of 0.962.

In order to determine system availability, find $P'_{0(FA)}$ for 1 ping,

thus: $P'_{0(FA)} = e^{-\lambda}\lambda^x/x! = e^{-\lambda}$

For a 30 m active period and $P_{(FA)} = 0.5$, $P'_{0(FA)} = 0.9345$. Therefore, $P'_{(FA)}$ for 1 ping = 0.0655. Consequently, the probability of at least 6 of 8 echo ranging cycles with false alarms is given by:

$$P(m \geq 6) = P(6) + P(7) + P(8)$$

as $1.97 \times 10^{-6}$ in 569 ms, resulting in a mean time to false alarm of 55.6 hrs and essentially unity availability. Similarly, m = 5, n = 8 results in a $P'_{(D)}$ of 0.995 and a mean time to false alarm of 1.9 hrs.

## 1.2 Detection Statistics, Downward Channel

The echo excess (EE), the amount the echo exceeds the requirements set by the detection statistics, is given as follows:

$$EE = EL - RML$$

where the echo level (EL) is:

$$EL = SL - 2TL + TS$$

where SL = Source Level
TL = Transmission Loss
TS = Target Strength

and the reverberation masking level (RML) is:

$$RML = RL_v - 10 \log w' + 5 \log dw/t \text{ for } wt \gg 1$$

where the volume reverberation level ($RL_v$) is:

$$RL_v = SL - 2TL + S_v + 10 \log ct/2 + [10 \log (b_1/2) + 10 \log (b_2/2) - 31.6] \quad \text{(in dB)}$$

where $w'$ = Signal Bandwidth
$w$ = Receiver Bandwidth
$S_v$ = Volume Scattering Coefficient
$b_1$, $b_2$ = Beam Width, 2 axes
$d$ = Detection Index
$t$ = Pulse Length
$c$ = Sound Velocity

Assume suitable detection statistics for the fully extended mode:

$$P_{(D)} = 99\%, \; P_{(FA)} = 0.02\%, \; d = 36$$

In this case, figure 12.11 of reference 7.3 requires an additional 12 dB of echo level if $wt = 1$.

Hence, in that case,

$$RML = RL_v - 10 \log w' + 5 \log dw/t + 12 \quad \text{(in dB)}$$

resulting in

$$EE = -TL + TS - S_v - 10 \log ct/2 - 10 \log (b_1/2) + 10 \log (b_2/2) + 10 \log w' - 5 \log dw/t + 31.6 - 12 \quad \text{(in dB)}$$

In the selected design,

$w' = w = 4$ kHz, $t = 0.25$ ms, $d = 36$
$c = 1500$ m/s, $b_1 = 16.8$ degrees, $b_2 = 28$ degrees

TL = 17 dB ref 1 m at 7 m range assuming spherical spreading and an absorption coefficient of 48 dB/km at approximately 200 kHz

TS = -44 dB based on reference 7.1 extended to a 0.01 $m^2$ ice target at a frequency of approximately 200 kHz

$S_v$ = -50 dB based on reference 7.3

yielding

EE = 12.2 dB

For the assumed value of $P_{(FA)}$, the probability of exactly x false alarms in the time t' is given by the Poisson distribution:

$$P'_{(FA)} = e^{-\lambda}\lambda^x/x! \qquad \text{where } \lambda = P_{(FA)}\, t'/t$$

To find t' for $P_{0(FA)} = 0.5$ where x = 0 (i.e. 0.5 probability of no false alarm),

$e^{-\lambda} = 0.5$ and $\lambda = 0.693$ giving $t' = 31.5$ s.

For a 7 m active period (r) and 71.1 ms pulse repetition rate ($T_r$), the receive duty cycle (D), where

$$D = [(2r/c) - t]/T_r = 0.128,$$

results in a mean time without false alarm of 246 s. If the following assumptions are made with respect to dead time du to a false alarm induced retraction:

| Activity | Time (ms) |
|---|---|
| Seek to Hide mode | 1339 |
| 4 Downward Soundings | 284 |
| Hide to Peek Mode | 843 |
| 8 Forward Pings | 569 |
| Peek to Seek mode | 495 |
| Total | 3530 |

then an availability of 0.986 results.

### 1.2.1 Multiple Echo Correlation Post Processing

An m-out-of-n correlation post processor is used to improve $P_{0(FA)}$ and system availability.

If m = 3 and n = 4 is considered for a 569 ms detection period, then, for the assumed design statistics, the cumulative binomial distribution

$$P(m \geq 3) = P(3)\ P(4)$$

where $P(m) = \{n!/[m!(n-m)!]\}\pi^{m}(1-\pi)^{n-m}$ and $\pi = 0.99$

results in a $P'_{(D)}$ of 0.9994.

In order to determine system availability, find $P'_{0(FA)}$ for 1 ping,

thus: $P'_{0(FA)} = e^{-\lambda}\lambda^{x}/x! = e^{-\lambda}$

For a 7 m active period and $P_{(FA)} = 0.02\%$, $P'_{0(FA)} = 0.9928$. Therefore, $P'_{(FA)}$ for 1 ping equals 0.00724. Consequently, the probability of at least 3 of 4 echo ranging cycles with false alarms is given by:

$$P(m \geq 3) = P(3)\ P(4)$$

as $1.488 \times 10^{-4}$ in 284.4 ms, resulting in a mean time to false alarm of 36.8 hrs and essentially unity availability.

# APPENDIX B

## CTL REPORT NO. 1064, "REQUIREMENTS FOR A RUGGEDIZED TRANSDUCER FOR ICE HAZARD DETECTION SONAR"

| REVISIONS | | | |
|---|---|---|---|
| LTR | DESCRIPTION | DATE | APPROVED |
| A | Replaces Rev "-" with change, ECO No. 2107 | 04 Nov 88 | BA RVdB |

REPLACES REV - WITH CHANGE

PROPRIETARY

| REV | A | A | A | A | A | A | A | A | A | A | A | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHEET | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | | | | | | | | | | | | | | |
| REV | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| SHEET | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |

GTECH LTD.
525 BOUNDARY ROAD
CORNWALL, ONTARIO K6H 6W7

# REQUIREMENTS FOR A RUGGEDIZED TRANSDUCER SUBSYSTEM FOR ICE HAZARD DETECTION SONAR

| | | |
|---|---|---|
| PREPARED | 4 NOV. 88 | XLL |
| CHECKED | 4 NOV. 88 | BA |
| APPROVED | 04 NOV 88 | RVdB |

REPORT NO. 1064

SHEET 1 OF 36

C-T557

<<<<<<<< N O T E >>>>>>>>

**CHARACTERS AND INFORMATION MUST BE ADDED TO THE SHEETS AS LISTED BELOW BEFORE USING THIS REPORT AS AN ORIGINAL.**

**SHEETS 15 & 17:**

Add the lambda symbol to the following:

$p'_{(Fa)} = e^{-Lambda}\ Lambda^{x}/x!$ where $Lambda = P_{(Fa)}t'/t$

$e^{-Lambda} = .5$

and $Lambda = .693$

thus $p'_{\theta(Fa)} = e^{-Lambda}\ Lambda^{x}/x!$

$= e^{-Lambda}$

**SHEET 22:** Paragraph 3.3.3.5. Add degrees symbols to:

5 10 15 20 25 30

and

35 30 25 20 15

**SHEET 24:** Tables missing. Print Tables in Filename "ICET12" on blank sheet 24.

**SHEET 30:** Paragraph 3.4.2.3.1.4.6. Add degrees symbols to 978, 360, and 45.

**SHEET 32:** Reference Memory Initialization Sequence

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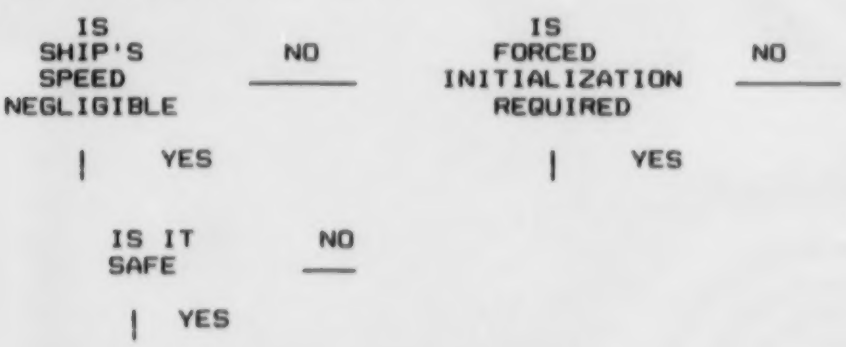


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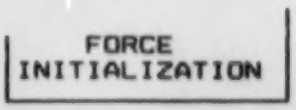


**SHEET 36:** Block diagram is missing from this printout.

**SHEET 1:** Replace this sheet 1 with a Report cover sheet (C-T577)

| CTL REPORT No. | 1064 |
|---|---|
| REV | SHEET 1 |

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# REQUIREMENTS FOR A RUGGEDIZED TRANSDUCER SUBSYSTEM FOR ICE HAZARD DETECTION SONAR

## 1.0 SCOPE

This report addresses system design related issues for a ruggedized transducer subsystem for an ice hazard detection sonar as proposed i C-Tech Ltd Report No. 975 and will serve as the guiding document fo the remaining system design work, interface design, and test plan development.
Specifically, the operational requirements are reviewed, desig trade-offs for the proposed seek-and-hide concept are examined, an an appropriate implementation is defined via a system block diagram.

## 2.0 ANALYSIS OF OPERATIONAL REQUIREMENTS

### 2.1 ICE RELATED OPERATIONAL REQUIREMENT

#### 2.1.1 GENERAL CONSIDERATIONS

It is expected that the MV Arctic will be used for the syste installation and sea trials, as the main CDS-40A Sonar has al- ready been fitted. The following considerations assume the use of the ship.
Maximum ship's speeds of 18 knots in open water and 10 knots during ice breaking operation are projected.
It is anticipated that during ice ramming operation the ship's speed in reverse is not greater than approximately 2 knots.
Main sonar forward detection capability is not needed when re- versing; additionally the probability of rear collision of the transducer with broken ice is high. It is therefore proposed that the transducer be retracted in this mode.

**Life Expectancy**
In view of the experimental nature of the program, the system will be designed with a life expectancy satisfactory for one season's operation by skilled personnel; use of the system outside these constraints is not anticipated or recommended.
Additionally, the provision of data gathering capability is limited to the sea trial phase only.

#### 2.1.2 DETECTION RANGE AND FIELD

**2.1.2.1 Main transducer**
The main transducer will be a ruggedized version of the CDS-40A Sonar Transducer.

**2.1.2.2 Proximity transducers**
Two proximity transducers are proposed; one to sense threa- tening ice mass in the forward direction, the other to sen- se ice hazard below the transducer when moving from hide to peek modes.
The proximity transducers are dimensionally restricted to be compatible with the existing main transducer (CDS-40A), and are therefore limited to an approximate maximum dia- meter of 152.4 mm.

**Transducer Element**
The transducer bandwidth must be compatible with the basic acoustic pulse width.

**Operating frequency**
The minimum operating frequencies of both the forward and downward looking proximity transducers are limited by the available space on the bottom of the main transducer. All variables must be considered in the operating frequency selection; additional variables include: beam width, detection range, sensitivity and speed of retraction.

2.1.2.3 **Detection/Response**
Detection range and compatible response time will be optimized for ice masses of 1 Kg and over per CTL Report 975. The transducer system must be ice hardened to withstand impact with an ice mass of approximately 1 Kg travelling at a relative speed of 18 Knots.

**Speed of retraction/available space**
For best performance and response time, the retraction mechanism should be designed to use hydraulic power. This requires additional space for an oil supply tank and an accumulator. The space can be reserved in a nearby remote location; its size would be approximately 762 mm long x 610 mm wide x 508 mm high.

2.1.2.4 **Hide-Peek-Extend Retraction Mechanism Cycle**
The retraction mechanism is designed to initially lower the transducer until its bottom comes in line with the bottom of the ship's hull (Hide mode). Once the ice detecting mechanism is activated and no alarm message is received by the hoist control, the transducer is lowered to a peek mode (only the proximity transducer is exposed). The proximity sounder detection capability is extended to include a partial forward detection mode, and again, if no target is detected, a signal is sent to the hoist control to activate the extension mechanism and lower the transducer to its fully extended position. While in the fully extended position, the proximity transducer and sounder continue the near field ice detection with full forward detection capability. The presence of ice or foreign objects in the near field area will cause a transducer retraction into the Hide position, and the cycle begins again.

**Cable flexibility**
Also to be considered in the speed of retraction is the transducer cable flexibility, since this is the communication link and has to move along with the mechanism.

**Transducer position feedback**
Transducer position feedback will be provided for the data collection phase, to allow correlation with acoustic data.

2.1.3 **ICE FLUX**

As mentioned in CTL Report No. 975, no data is available on the ice flux density under the ship's hull. In the vicinity of the

existing transducer location in the MV Arctic, it is believed that the ice flux is relatively low for the following reasons:

a) The bow is designed to move the ice to the side
b) Little ice goes deep, evidenced by the fact that the ship's propellers rarely mill the ice
c) Because of energy considerations, it is unlikely that a chunk of ice will be pushed down to the depth of the bottom of the hull, if this depth is 11 metres.

However, one cannot discount the possibility of ice becoming trapped under the hull by a piling up mechanism or by sliding down the bow under the force of the movement of the water relative to the hull.

## 2.2 SHIP RELATED ENGINEERING REQUIREMENTS

### 2.2.1 PHYSICAL REQUIREMENTS

1) Ship's drawings for review re accessibility, cable routing, hull shadowing, bubbler location and other noise sources.
2) Availability of existing CDS-40 hardware on MV ARCTIC, including the existing "Audio & Recorder Interface Unit" P/N 12918, is assumed.
3) Additional cabling required as detailed below.

#### 2.2.1.1 SPACE AND ACCESSABILITY

**Operations Area**
An operations area allowing ready and continual access by as many as three persons during the sea trial phase is required.
Communications with the bridge should be readily available for trail direction, and a view of the external situation would be a definite asset.
(Operations area equipment miscellaneous cable interconnection requirements not included).

##### 2.2.1.1.1 Control Indicator (CI)

The ideal location for the CI is in the Operation Area.
Approximate dimensions (mm): 489 deep x 578 wide x 343 high.

##### 2.2.1.1.2 Audio & Recorder Interface Unit

Located near the CI and Data Recorder.
Access to controls required during sea trial data collection phase.
Approximate dimensions (mm): 260 deep x 203 wide x 130 high.

##### 2.2.1.1.3 Video Cassette Recorder

Located near CI, requires access to 115 VAC ship's power.
Access to controls required during sea trial data collection phase.
Approximate dimensions (mm): 375 deep x 432 wide x 95 high.

2.2.1.1.4 **Proximity Sounder**
The ideal location for the proximity sounder unit is next to the CI.
Access to controls required during sea trial data collection phase.
Approximate dimensions (mm): 508 deep x 381 wide x 457 high (May be larger with additional hard-ware).

2.2.1.1.5 **Power Supply**
Located within 3.0-4.0 m of proximity sounder, requires access to 115 VAC ship's power.
Approximate dimensions (mm): 419 deep x 483 wide x 88 high. Typical ( depends on the supply selected).

2.2.1.1.6 **Data Recorder**
Located next to proximity sounder for sea trial only, requires access to 115 VAC ship's power.
Access to controls required during sea trial data collection phase.
Approximate dimensions (mm): 192 deep x 383 wide x 320 high (typical) or 619 deep x 483 wide x 155 high (typical) (depends on the recorder selected).

2.2.1.1.7 **TR Unit**
The TR unit is designed to operate best when mounted next to the retraction mechanism. The transducer is assembled with only 4.0 to 4.6 m of cable for the purpose of maintaining the TR unit in its proximity.
A small extension to the transducer cable may be possible but not without costly redesign work or significant loss in noise performance and/or sensitivity.
Temperature and humidity should be controlled to provide a non-condensing environment.
Unit location is expected to remain as in the present CDS-40A installation; the previously installed 1500 W thermostatically controlled heater could satisfy this requirement.
Approximate dimensions (mm): 290 deep x 610 wide x 640 high.

2.2.1.1.8 **Hoist Controller**
The main control can be located either next to the retraction mechanism or at some distance away; maximum distance would depend on the retraction method used (electric or hydraulic).
Approximate dimensions (mm): 305 wide x 381 high x 203 deep.

The remote control unit is located within the CI.

2.2.1.1.9 **Hoist Power Unit**
For best efficiency and performance, the hoist power unit should be part of the retraction mechanism; however, if the hydraulic method is used, the unit could be located in a remote area near by.
Approximate dimensions (mm).
Hydraulic: 686 long x 508 wide x 762 high.
Electrical: Part of the retraction mechanism.

2.2.1.1.10 **Retraction Mechanism & Transducers**

These units must be hull mounted with access to the underwater environment at a maximum depth (ship's bottom) and in a location where:

a) The ice flux, during ice-breaking mode, is at minimum
b) The transducer path is unobstructed by hull protrusions or ship's apparatus
c) The transducer is as far forward as possible from the ship's propeller.

Unit location expected to remain as in present CDS-400 installation.

Approximate dimensions (mm): 406 wide x 406 deep x 1220 high.

2.2.1.1.11 **Major Connecting Cable Runs**

CI-TR

Communication and power cables are required between the control indicator and the transmitter/receiver units. Space and access holes must be provided to run these cables. The space and hole sizes should be large enough to allow the connectors to pass through. If necessary, the connectors could be installed on site but, it is not recommended since the system is tested with the supplied cables and connectors.

Approximate clearance hole size (mm): 38.1 diameter.

**Proximity sounder to transducer**

Two cables are required from the sounder; one to the proximity transducers and one to the hoist controller. These cables can be run in the vicinity of the CI-TR communication and power cables. These cables will also require a hole approximately 38.1 mm in diameter. As mentioned in paragraph 2.2.1.1.12.3 additional tuning and matching will be required for distances greater than 15 m.

**Sounder-Hoist controller**

A communication cable is required to supply lowering/retracting information to the retraction mechanism; this cable is approximately 6.5 mm in diameter and it is terminated with a connector.

Approximate clearance hole size (mm): 32 in diameter.

**Hoist controller to retraction mechanism**

The cable requirement between the hoist controller and the retraction mechanism varies depending on the method used. The possible variations are listed below:

1) Electrically powered retraction mechanism.
   The hoist control unit will be installed on the retraction mechanism; this limits the requirement to one power cable from the ship's supply.
2) Hydraulically powered retraction mechanism.
   In this application, the requirement is for ship's power to the pump motor via the hoist control. Additional electrical and fluid power line requirements depend on the location of the hydraulic power supply and valve location. The general requirement

is a cable to the limit switches and valve solenoid, and hydraulic lines to the valve and the cylinders.

2.2.1.1.12 **Distance Between Units**

2.2.1.1.12.1 **Control Indicator - TR Unit**
Assuming the use of the MV Arctic and the present system location, the distance between the CI and TR unit is approximately 250 m.

2.2.1.1.12.2 **TR unit - Transducer**
This distance must be kept to a minimum, not greater than 1.5 m is recommended.

2.2.1.1.12.3 **Proximity Sounder to Proximity Transducer**
Local tuning and matching will be required if the distance between the proximity transducer and the sounder is greater than 15 m; it is likely that this distance will be approximately 250 m.

2.2.1.1.12.4 **Hoist Controller - Hoist Power Unit - Retraction Mechanism**
It is desirable to position the hoist power unit and controller next to the retraction mechanism; however, for practicality the hoist controller can be located some distance away. Further, subject to the condition on the electric vs hydraulic retraction systems, the hoist power unit may also be located in a near by area.

2.2.1.1.13 **Transport ports**
Although the system can be dismantled for trans-portation into the sonar compartment, some of the sub-assemblies require a good size opening (larger than some manholes found in ships). The following are approximate dimensions for the non-dismountable sections:

a) TR unit enclosure: 610 x 610 x 305 mm with reasonably square corners.

b) Transducer support shaft and transducer assembly: Approximately 152-178 mm in diameter for a length of 457-584 mm and 102-152 mm diameter for the next 1524-1780 mm of length.

## 2.2.2 SYSTEM INSTALLATION

### 2.2.2.1 SYSTEM ACCESS FOR INSTALLATION/REPAIR

2.2.2.1.1 **TR transport**
The TR unit resides next to the retraction mechanism and transducer assembly. Access holes are required for transporting this unit.

2.2.2.1.2 **Hoist power unit transport**
The hoist power unit, if hydraulic, would require an access hole approximately 711 mm in diameter. Other dimensional configurations could be considered while designing this unit.

2.2.2.1.3 **Retraction mechanism transport and installation**
The approximate opening required to transport the retraction mechanism is 660 mm in diameter. Some dismantling is possible to reduce its length, but the longest section can only be reduced to approximately 1520-1780 mm. Once in the sonar compartment, additional space would be required (610-762 mm) for transducer reassembly. Transducer dismantling from the supporting shaft is not recommended.

2.2.2.1.4 **Transducer transport installation**
It is preferable to install the transducer onto the retraction mechanism prior to transporting the assembly to the sonar compartment. If dismantling is required, it should be only to the point where the transducer remains with the retraction mechanism shaft. A lifting device capable of handling approximately 136-227 Kg will be required to transport the assembly.
The present bottom gear and transducer assembly must be removed to allow installation of the above mentioned retraction mechanism. Further dismantling of the flanged pipe extension, directly above the gate valve, may also be required.

## 2.2.3 INTERFACES

### 2.2.3.1 MECHANICAL

#### 2.2.3.1.1 RETRACTION MECHANISM CONTROLS

2.2.3.1.1.1 **Main**
If electric power is used to operate the retraction mechanism and the available space allows it, the main control unit will be mounted on the side of the retraction mechanism unit.
If hydraulic power is used, the main control can be remotely located.

2.2.3.1.1.2 **Remote**
Either the electrically or hydraulically operated retraction mechanism will have an electrically operated remote control.

### 2.2.3.2 POWER REQUIREMENT

2.2.3.2.1 **Control Indicator**
115 VAC 50/60 Hz 500 W

2.2.3.2.2 **Proximity Sounder**
115 VAC 50/60 Hz 250 W

2.2.3.2.3 **Data Recorder**
115 VAC 50/60 Hz 125 W (depends on the recorder selected)

2.2.3.2.4 **TR unit**
Power supplied by the control indicator.

2.2.3.2.5 **Hoist Control**
115 volts AC 200 watts.

2.2.3.2.6 **Hoist power unit/retraction mechanism**
The power required is dependant on the speed of retraction; however, the minimum retraction power requirement is in the 4000-5000 watts range. Although the system is designed to operate with 115 volts AC power, the retraction mechanism could be designed to accept hydraulic power from the ship. The hydraulic pressure required is in the 17.2-2.07 MPa range with a minimum flow of 11 litres per minute (l/min). Over and above the hydraulic power, the retraction mechanism also uses 115 volts AC for the controls; this requirement should not be greater than 500 watts. If electrical power is used in place of the hydraulic power, this would be in the range of 4000-5000 watts to supply the hydraulic pump or the retraction motor and clutch.

Electrical power: 115 volts AC 60 Hz 4000-5000 W or
Hydraulic power: 11 l/min of fluid at 17.2 MPa.

2.2.3.3 SHIP's LOG

Ship's log data is required to provide both forward and reverse speed data for optimum proximity sounder signal processing and for the data analysis phase. The log data format and interface requirements must be available for the hardware design phase.

2.2.4 SAFETY ASPECTS

It is assumed that operation in a potentially explosive environment is not a requirement. Confirmation is important as the scope of the initial proposal would be exceeded in the event of this requirement.

2.2.4.1 **Control Indicator & Proximity Sounder**
No danger of electrical or mechanical shock exists if properly installed and protected from water intrusion.

2.2.4.2 **TR unit**
The TR unit is fully enclosed in a metal cabinet with only the connectors protruding on one side; no danger of electrical or mechanical shock exists if properly installed.

2.2.4.3 **Hoist controller**
The hoist controller is located next to the retraction mechanism; it is fully enclosed and presents no danger to the bystander

2.2.4.4 **Hoist power unit**
The hoist power unit, if of the hydraulic type, would have steel braided lines, both to maintain high efficiency and to provide protection of personnel in the event of puncture.

2.2.4.5 **Retraction Mechanism**
The retraction mechanism is fully covered to protect personnel. Full retraction over the gate valve is provided

to allow the gate valve to be closed. Included for system safety are auto-retraction in the event of a signal cable failure and means for manual retraction in the event of a hoist power unit failure.

2.2.4.6 **Frangible points**
In order to maintain the safety integrity of the gate valve, frangible points are created at the proximity-main transducer and main transducer-retraction mechanism interfaces. In the event of an ice collision while in peek or seek modes the transducer section is allowed to separate from its interfaced section without losing the water seal integrity, therefore allowing safe retraction above the gate valve.

2.2.4.7 **Transducer replacement**
Although the system and the retraction mechanism are designed to detect oncoming ice and safely retract when the danger is foreseen, the possibility of transducer collision with the ice must not be ignored. Provisions are made to allow transducer replacement in the field. In the event that the transducer is damaged, it can be replaced by running the retraction mechanism to its fully retracted position, closing the gate valve, and partially dismantling the retraction mechanism. For this reason the sonar compartment area has to be made accessible with provision for the use of hand held lifting devices.

## 2.3 EQUIPMENT REQUIRING DEVELOPMENT

The following equipment requires development:

a) Proximity Sounder and Alarm Signal Processing
b) Proximity Transducers
c) Ruggedized Transducer
d) Hoist Controller
e) Hoist Power Unit
f) Retraction Mechanism

## 2.4 SEA TRIALS RELATED REQUIREMENTS

2.4.1 **System Installation**
Must precede the sea trials; it is anticipated that three people (2 engineers, 1 technician) can complete this task with approximately 40 hrs of parallel access (120 man hours).

2.4.2 **Test Program**
It is estimated that a test program of some six dedicated ships days is needed, perhaps taken during a seven to nine day total. Some tests could be carried out prior to entering an arctic harbour, the balance upon departure.
The test program is to assess the performance, reliability and availability of the transducer portion of the ice detection sonar, and should provide quantitative evaluation data for system availability, time to repair in the event of damage, the acoustic environment, and the ice environment.

2.4.3 **Operation Area**
An operations area is required to house equipment and as many as three personnel to support trials direction, data taking,

recording, and analysis on board the trial ship.
Requirements are further discussed in para. 2.2.1.1 and 3.4.4.2.

2.4.4 **Equipment Access**
In addition to full access to the operations area, access should also be available to the retraction mechanism to allow observation, adjustment, and repair as necessary during the sea trial.

2.4.5 **Personnel**
A Sea Trial Director, support engineer, and technician are projected; details regarding operational flexibility, e.g. shifts required, should be considered. A ship's voyage of approximately 10 days is anticipated.

## 2.5 RESULT REQUIREMENTS

The sea trial data must be analyzed and a project technical report prepared to describe the project tasks, achievements and methodology, and to provide a system description and detailed specification.
The report shall be prepared in accordance with TDC Publication Standards and Guidelines for Contractors, TP929.

# 3.0 TRADE OFF ANALYSIS

It is assumed that the basic mechanism for transducer protection will use the "seek-and-hide" concept outlined in the proposal (DDS file No. 12SD.T8200-7-7528-A. CTL Report No. 975).
Although other concepts could be envisioned, such as an array of mechanically actuated compliant feelers ahead of the transducer, these will not be considered here.
The trade-off analysis will be completed and validated as required in the remaining system design phases.

The proposed system consists of four major developments:

a) Ruggedize the main transducer to withstand impact with smaller chunks, of at least a kilogram mass, at a speed of 18 knots.
b) Provide a proximity sounder system to supply advance warning of impending collision with larger ice masses.
c) Provide an improved hoist subsystem to retract the transducer as required to avoid the projected threat.
d) Provide acoustic data collection and ice flux monitoring capability for subsequent analysis.

This system should function to maintain reliable main sonar ice mass detection capability; i.e., the transducer must have satisfactory life expectancy consistent with good detection probability and low false alarm rate.
In addition the system should be designed to provide ease of replacement of transducer in the event a failure does occur.

## 3.1 GENERAL AND ENVIRONMENTAL

3.1.1 **Sounder frequency**
Although the forward sounder is limited in size, it should also be capable of producing a source level sufficient to provide a

good signal to noise ratio in the ice environment. Further, reducing the frequency from 130 KHz to 80 KHz will give an increase of approximately 6 dB (Ref. CTL Report No. 813) in target strength; however if the decreased acoustic size realizes larger beamwidths, the false alarm rate may increase to an unacceptable level.

3.1.2 **Detection statistics, forward channel**

The echo excess (EE), the amount the echo exceeds the requirements set by the detection statistic, is given as follows:

$$EE = EL - RML$$

where the echo level is

$$EL = SL - 2TL + TS$$

where SL=Source Level, TL=Transmission Loss, TS=Target Strength

and the reverberation masking level is

$$RML = RL_s - 10\log w' + 5\log dw/t \quad \text{for } wt >> 1$$

where the hull surface reverberation level is

$$RL_s = SL - 3TL/2 + S + 10\log ct/2 + [10\log (b/2) - 12.6]$$

w'= Signal Bandwidth, d = Detection Index,
w = Receiver Bandwidth t = Pulse Length
S = Surface Scattering c = Sound Velocity
b = Beam Width

Assume suitable detection statistics for the fully extended mode:

$$P_{(D)} = 90\ \%,\ P_{(Fa)},\ 1\ \%,\ d = 16$$

In this case figure 12.11 of Urick[1] requires an additional 2 dB of echo level if wt = 11.

Hence, in that case

$$RML = RL_s - 10\log w' + 5\log dw/t + 2$$

then,

$$EE = -\tfrac{1}{2}TL + TS - S_s - 10\log ct/2 - 10\log b/2 + 10\log w' - 5\log dw/t + 12.6 - 2 \quad (dB)$$

As an example for the anticipated design , set:

w' = w = 4 KHz, t = 2.75 ms, d = 16
c = 1500 m/s, b = 25 degrees (Ref. Para. 3.3.3.3)

TL = 26.5 dB ref 1 m at 20 m range (spherical spreading $\alpha \cong 24$ dB/Km @ 80 KHz)

TS = -32dB[1], $S_s$ = -50 dB[1], (the coefficient for a smooth hull surface is expected to be lower than for sandy bottom)

EE = .4 dB

---

[1] Based on CTL Report No. 813, extended to a 0.01 $m^2$ ice target at a frequency of 80 KHz.

For the assumed value of $P_{(Fa)}$, the probability of exactly x false alarms in the time t' is given by the Poisson distribution

$$p'_{(Fa)} = e^{-\lambda}\lambda^x/x! \qquad \text{where} \quad = P_{(Fa)}t'/t$$

to find t' for $p'_{e(Fa)} = .5$ where $x = 0$

$$e^{-\lambda} = .5$$

and $\lambda = .693$

giving $t' = 381$ ms

For a 30 m active period (r) and 71.1 ms pulse repetition rate ($T_r$), the receive duty cycle

$$D = [(2r/c)-t]/T_r$$

$$= .524$$

resulting in a mean time without false alarm of 727.5 ms. If the following assumptions are made with respect to dead time due to a false alarm induced retraction (ref. para. 3.1.4),

| | Activity | Time (ms) |
|---|---|---|
| | Seek to Hide mode | 1339 |
| * | 4 Downward sounding | 284 |
| | Hide to Peek mode | 843 |
| * | 8 Forward pings (ref. para. 3.1.2.1) | 569 |
| | Peek to Seek mode | 495 |
| | Total | 3530 |

then an availability of .171 results.

3.1.2.1 Multi ping post processing

An m-out-of-n detection scheme could be considered to improve $p'_{e(Fa)}$ and system availability.

If m=6 and n=8 is considered for a 569 ms detection period, then, for the statistics assumed in paragraph 3.1.2, the cumulative binomial distribution

$$P(m\geq 6) = P(6) + P(7) + P(8)$$

where $P(m) = (n!/[m!(n-m)!])\pi^m (1-\pi)^{n-m}$ and $\pi=.9$

results in a $P'_{(D)}$ of .962

In order to determine system availability, find $p'_{e(Fa)}$ for 1 ping

thus $p'_{e(Fa)} = e^{-\lambda}\lambda^x/x!$

$$= e^{-\lambda}$$

For a 30 m detection period and $P_{(Fa)}$ .5% $p'_{e(Fa)} = .9345$. Therefore p' (Fa) for 1 ping equals .0655. Consequently, the probability of at least 6 of 8 echo ranging cycles with false alarms is given by

$P(m \geq 6) = P(6) + P(7) + P(8)$ as $1.97 \times 10^{-4}$ in 569 ms resulting in a mean time to false alarm of 55.6 hrs and essentially unity availability. Similarly m=5, n=8 results in $P'_{(D)}$ of .995 and a mean time to false alarm of 1.9 hrs.

### 3.1.3 Detection statistics, downward channel

The echo excess (EE), the amount the echo exceeds the requirements set by the detection statistic, is given as follows:

$$EE = EL - RML$$

where the echo level is

$EL = SL - 2TL + TS$ where SL=Source Level, TL=Transmission Loss, TS=Target Strength

and the reverberation masking level is

$RML = RL_v - 10\log w' + 5\log dw/t$ for $wt >> 1$

where the volume reverberation level is

$RL_v = SL - 2TL + S_v + 10\log ct/2 + [10\log (b1/2) + 10\log (b2/2) - 31.6]$

w'= Signal Bandwidth, d = Detection Index,
w = Receiver Bandwidth t = Pulse Length
S = Surface Scattering c = Sound Velocity
b1 b2 = Beam Width, 2 axes

Assume suitable detection statistics for the fully extended mode:

$$P_{(D)} = 99\ \%,\ P_{(Fa)} = .02\ \%,\ d = 36$$

In this case figure 12.11 of Urick [1] requires an additional 12 dB of echo level if $wt = 1$.

Hence, in that case

$RML = RLs - 10\log w' + 5\log dw/t + 12$

then,

$EE = -TL + TS - S_v - 10\log ct/2 - 10\log (b1/2) + 10\log (b2/2) + 10\log w' - 5\log dw/t + 31.6 - 12$ (dB)

As an example for the anticipated design, set:

$w' = w = 4$ KHz, $t = .25$ ms, $d = 36$
$c = 1500$ m/s, b1 = 16.8 degrees b2 = 28 degrees
TL = 17.2 dB ref 1 m at 7 m range (spherical spreading, $\alpha = 40$ dB/Km @ 200 KHz)

TS = -44dB [4], $S_v$ = -75 dB [1].

EE = 12.2 dB

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[4] Based on CTL Report No. 813, extended to a 0.01 $m^2$ ice target at a frequency of 200 KHz.

For the assumed value of $P_{(Fa)}$, the probability of exactly x false alarms in the time t' is given by the Poisson distribution

$$p'_{(Fa)} = e^{-\lambda}\lambda^x/x! \qquad \text{where } \lambda = P_{(Fa)}t'/t$$

to find t' for $p'_{e(Fa)} = .5$ where x = 0

$$e^{-\lambda} = .5$$

and $$\lambda = .693$$

giving $$t' = 31.5 \text{ s}$$

For a 7 m active period (r) and 71.1 ms pulse repetition rate ($T_r$), the receive duty cycle

$$D = [(2r/c)-t]/T_r$$

$$= .128$$

resulting in a mean time without false alarm of 246 s.
If the following assumptions are made with respect to dead time due to a false alarm induced retraction (ref. para. 3.1.4),

| | Activity | Time (ms) |
|---|---|---|
| | Seek to Hide mode | 1339 |
| * | 4 Downward sounding | 284 |
| | Hide to Peek mode | 843 |
| * | 8 Forward pings | 569 |
| | Peek to Seek mode | 495 |
| | Total | 3530 |

then an availability of .986 results.

3.1.3.1 Multi ping post processing

An m-out-of-n detection scheme could be considered to improve $p'_{e(Fa)}$ and system availability.
If m=3 and n=4 is considered for a 569 ms detection period, then, for the statistics assumed in paragraph 3.1.3, the cumulative binomial distribution

$$P(m\geq 3) = P(3)\ P(4)$$

where $P(m) = (n!/[m!(n-m)!])x^m(1-x)^{n-m}$ and x=.99

results in a $P'_{(3)}$ of .9994

In order to determine system availability, find $p'_{e(Fa)}$ for 1 ping
thus $$p'_{e(Fa)} = e^{-\lambda}\lambda^x/x!$$

$$= e^{-\lambda}$$

For a 30 m detection period and $P_{(Fa)}$ .02% $p'_{e(Fa)}$=.9920.
Therefore p'(Fa) for 1 ping equals .00724.
Consequently, the probability of at least 3 of 4 echo ranging cycles with false alarms is given by

$P(m \geq 3) = P(3)\ \ P(4)$ as $1.488 \times 10^{-6}$ in 284.4 ms, resulting in a mean time to false alarm of 36.8 hrs and essentially unity availability.

### 3.1.4 Detection range vs retraction time

Based on a maximum ship's speed of 18 knots, time available for retraction is dependent on the detection range. Some detection ranges considered are shown below; these detection ranges include the time to accumulate complete date from ping cycles, signal processing and mechanical retraction.

| Detection range metres | Retraction time (including detection delay) seconds |
|---|---|
| 30 | 3.238 |
| 25 | 2.698 |
| 20 | 2.158 |
| 15 | 1.619 |
| 10 | 1.079 |
| 9 | .971 |
| 8 | .863 |
| 7 | .755 |
| 6 | .648 |
| 5 | .540 |

If forward detection is accomplished with data accumulated within two master sounder cycles of 284.4 ms and signal processing delay does not exceed one cycle, 1.30 seconds are available to complete retraction with detection at 20 m. (Ref. para 3.4.2.2.1)

## 3.2 ICE HARDENED TRANSDUCER

### 3.2.1 Main transducer

The main transducer is a CDS-40A modified by ruggedizing the frame and incorporating a flange which is directly interfaced with the outer cylindrical protective shield. This shield is terminated by a hemispherical section which contains the proximity transducers. In ruggedizing the transducer, the strength of the material used for the top and bottom covers will be evaluated as necessary to provide adequate impact resistance to small ice fragments.
It is expected that the existing CDS-40A transducer on the MV Arctic will be retrieved and modified.

#### 3.2.1.1 Transducer recalibration

It should be noted that a recalibration of the main transducer in conjunction with its related TR unit printed circuit boards should be performed to update the data in CTL Report No. 851, 17 Sept. 1985, "Calibration Data, Canarctic CDS-40A Refurbished System", since the electroacoustic characteristics will likely be impacted by the ruggedizing rework.
There is some interaction of the transducer with transmitter/receiver components; accordingly, two possibilities are recommended to preserve data integrity:

a) The existing TR PCB and transmitter module set from the MV Arctic sonar should be retrieved for the calibration

exercise at the C-Tech test facility, or:

b) a new PCB and module set could be used for the calibration and exchanged for those on the MV Arctic at system installation.

### 3.2.2 Proximity transducers

The proximity transducers can be ruggedized by extending the cylindrical protective shield, used to protect the main transducer, by a hemispherical dome enclosing both forward and downward detecting transducers. Methods of ruggedizing are: flat faced dome, centre member support and side member support.

Although enclosing the proximity transducers within a hemispherical dome may be the simplest and most effective method of ruggedizing, the curvature of the dome will deflect the sounding beam, modifying its pattern and possibly affecting its detection accuracy.

The flat faced dome method is similar to the hemispherical dome with the exception that the front of the array is flattened to prevent deformation of the array beam pattern.
In the centre member support method, the forward array would be split in two to three sections. The sections would contain horizontal reinforcements to buffer impact with small ice fragments and protect the vulnerable part of the array. The members would be of the circular ring type extending to the centre of the frame and to the bottom of the transducer to protect the downward array.

With the side member support, the forward array would be enclosed within a window frame extending to the bottom of the transducer to protect the downward array.
In both the centre and side member support methods, the array would be covered with a neoprene window vulcanized to the face of the transducer elements.

## 3.3 MECHANICAL SUBSYSTEM

### 3.3.1 Retraction Mechanism

Two methods are considered for the retraction mechanism:

a) Hydraulic/electric unit complete with an accumulator. With this power source it is possible to achieve fast and smooth operation in all extending/retracting phases. It allows flexibility in power unit placement, since it does not need to reside on the retraction mechanism unit. Fast response can be obtained by charging the accumulator during idle time and discharging for quick retraction time.

b) Electromechanical power via a ball screw and clutch.
Using this type of power source, fast response can be obtained by keeping the ball screw running. In this method the mechanical parts, such as the ball screw, ball nut, bearings, supports, etc., need to be rugged and properly lubricated to withstand the continuous cycling operation, especially during the hide-peek-hide mode demands. Power demand for this application is high when fast response is a requirement.

Both methods have their pros and cons; however, hydraulic would be preferred since it would be the most efficient for fast response, high force multiplication and long term reliability, especially in repetitious cycling mode.

3.3.1.1 Power requirement

The power requirement for the retraction mechanism is highly dependent on the speed of retraction, which in turn is dependent on the time available from the moment that the oncoming ice is detected. In order to minimize the overall power requirement, consideration must be given to the hydraulic/accumulator method.

3.3.2 Speed of retraction

Speed of retraction is dictated by the detection range and the ship to ice speed and limited by other variables such as: Power available, cable flexibility, space, etc. For the projected ship to ice speed of 18 knots and a detection distance of 20 meters, the maximum projected retraction time is approximate 2 seconds; a faster retraction time would allow retraction on closer ice fragments. This retraction time can be accomplished with approximately 3-5 HP if the travel is not greater than 381 mm. However, if a lower operating frequency is used to improve the probability of detection, Ref. decreasing target strength vs frequency per CTL Report 813, "A Study Determining The Target Strength of Glacial Ice as a Function of Acoustic Frequency", more travel will be required to accommodate the larger array height. By increasing the travel, the power requirement and size of the retraction mechanism are also increased.
(The operating frequency used for initial design consideration was 130 KHz per the proposal CTL Report 975).
While in the ice breaking mode, the retraction mechanism may operate continuously; this will subject the cable to a cyclic bending. A longer travel may impose a greater stress to the cable.

3.3.3 PROXIMITY TRANSDUCER

3.3.3.1 Space available

Proximity transducer space is dependant on the available travel and the main transducer diameter. To optimize the system retraction time this should be maintained to less than 152 mm in diameter and 127 mm in height.

3.3.3.2 Detection range

Design is based on a minimum 20 meter forward detection range at a maximum forward speed of 18 knots. The downward proximity transducer is designed to detect up to 7 meters (Ref. para. 3.1.1).

3.3.3.3 Field of view

3.3.3.3.1 Forward Transducer

Azimuth - Wide enough to detect within turning radius @ 20m/18 knots, also to allow for turning of ice due to hull deflection. However, in this direction the field of view, including side lobes, must also be limited to control reverberation and to prevent return from sheet ice to port and starboard as the ship rolls.

Vertical - must be limited to minimize risk of bottom grazing within the detection distance when operating in shallow waters. The beam should also be depressed slightly to control hull grazing.

3.3.3.3.2 Downward Transducer

The beam should be limited to prevent intersection with the hull tube walls when sounding for ice directly under the tube from the hide position. The height is determined by the minimum ranging distance of .375 m for a 250 µs pulse length at 1500 m/s.

3.3.3.4 Operating frequency

Space available on the bottom of the main transducer and preferred vertical beam width for the forward proximity transducer may limit the frequency choice to a range greater than 60 KHz (Ref. decreasing target strength vs frequency per CTL Report 813, "A Study Determining The Target Strength of Glacial Ice as a Function of Acoustic Frequency"). A reduction of side lobe is necessary to minimize false alarm rate due to reflections from surface and/or bottom echoes, therefore consideration can be given to offsetting the element position in the active plane and vertical/horizontal alignment within the array. The possibility of using this method will be considered during the design stage to improve the probability of detection and the reliability of the system.

Based on the assumption that ice will not travel much deeper than the hull, we conclude that a short range is desired for the downward transducer.
Furthermore, to further reduce bottom echoes and allow more absorbtion loss, a higher frequency, possibly 200 KHz, is selected.

Downward detection

The downward transducer is needed to detect the ice passing along the hull. Detection must begin while the transducer is in the hide mode. Since the transducer position in relation to the hull (dictated by the detecting method used) may be a short distance above the hull, this area may fill with ice debris. To minimize the possibility of false alarms, the area immediately below the transducer must be kept clear. This is realized by lowering the transducer to just inside the hull to push the ice debris out of the tube and then retract to the detecting position. The cycle is repeated until a clear detection is obtained.

3.3.3.4.1 Mutual interference

In order to avoid mutual interference problems in the composite system, each of the three active subsystems (i.e., main sonar and two proximity sounders) must operate at a frequency whose fundamental and harmonics fall outside the receiving passband of the others.
Additionally, the sum and difference frequencies of any two subsystems should fall outside the receiving passband of the third to preclude nonlinear mixing.
Where the subsystems may be active in the same time frame, simultaneous keying should be used; this is,

however, not practical with respect to the main sonar because the length of its maximum ranging cycle would result in too low a data rate for the proximity sounders.

### 3.3.3.5 Configuration

The proximity transducers are mounted on the bottom of the main transducer and are directed toward the front and the bottom. Some of the operating frequencies considered are listed below along with possible beam widths and sizes. The beam widths considered at this point are based on some basic preliminary analysis of the environment.

Line Array Size/Frequency

Forward Array

| Frequency KHz | Beam Width at -3dB Vertical size mm 5° | 10° | 15° | Horizontal size mm 20° | 25° | 30° |
|---|---|---|---|---|---|---|
| 50 | 305 | 152 | 102 | 77 | 74 | 52 |
| 60 | 254 | 127 | 84 | 65 | 53 | 43 |
| 65 | 234 | 117 | 77 | 59 | 48 | 40 |
| 70 | 218 | 109 | 72 | 55 | 44 | 37 |
| 80 | 191 | 95 | 64 | 48 | 39 | 32 |
| 90 | 168 | 84 | 56 | 43 | 34 | 30 |
| 100 | 152 | 76 | 51 | 39 | 31 | 26 |
| 110 | 137 | 69 | 46 | 35 | 28 | 24 |
| 120 | 127 | 64 | 42 | 32 | 27 | 22 |
| 130 | 117 | 58 | 39 | 30 | 24 | 20 |

Downward Array

| Frequency KHz | Beam Width at -3dB Size mm 35° | 30° | 25° | 20° | 15° |
|---|---|---|---|---|---|
| 130 | 17 | 20 | 24 | 30 | 39 |
| 150 | 15 | 17 | 21 | 26 | 34 |
| 170 | 13 | 15 | 18 | 23 | 30 |
| 180 | 12 | 14 | 17 | 21 | 28 |
| 190 | 12 | 14 | 16 | 20 | 27 |
| 200 | 11 | 13 | 15 | 19 | 25 |

An additional 51-76 mm is required on the overall height of the transducer for mounting the proximity arrays.
Rear detection will not be provided. In order to protect the transducer when reversing, information must be derived from the ship's log to activate the retraction mechanism. Without this capability, the transducer, if in the operating mode, will be left unprotected from any ice arriving from behind the transducer.

### 3.3.3.6 Elements

Piezoelectric ceramic discs or blocks are available from various manufacturers for the assembly of the proximity transducers. The possibility of using the standard shapes along with the mass loaded method will be investigated in the detail design stage.
The element and array options with their related pros and

cons are provided in tables 3.3.3.6 A and 3.3.3.6 B. Preferred elements for both proximity transducers, as listed in the above mentioned tables, are the ceramic blocks because of the mounting and shading possibilities that they present.

TABLE 3.3.3.4 A. PROXIMITY TRANSDUCER ARRAY (FORWARD)

| TRANSDUCER ARRAY | ELEMENT SIZE ** | ARRAY SIZE ** | BEAM WIDTH DEG -3/-6dB | MTG & WIRING | Ga | Ge | SHADING | Ke | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|
| CERAMIC DISK 80 KHz | 123.0 DIA | 123.0 DIA | 9.8/ 12.2 | NOT PRACTICAL | N/A | N/A | FRAME ONLY | .5 | Element to large and beam width to narrow. |
| CERAMIC ROD 80 KHz | 6.99 DIA 17.8 LG | 95.3 X 39.4 | 18/13.5 X 25/34 | POOR | N/A | N/A | 4 STEP + MECH | .73 | Wiring may be a problem since the silvered surface area is very small |
| MASS LOADED ELEMENT 80 KHz | 12.7 SQ | 95.3 X 39.4 | 16.8/23 X 26/36 | 6000 | 6 | 0 | 4 STEP ELE + MECH | .144 | Requires development time |
| CERAMIC BLOCK 80 KHz $K_{31}$ MODE | 18 X 6.02 X16.02 | 95.3 X 39.4 | 16.8/23 X 28/28 | 6000 | 26 | .4 | 4 STEP + ELE OR MECH | .3 | Allows more shading possibilities but high Ga results in narrow acoustic pass band and long pulse requirement |

TABLE 3.3.3.4 B. PROXIMITY TRANSDUCER ARRAY (DOWNWARD)

| TRANSDUCER ARRAY | ELEMENT SIZE ** | ARRAY SIZE ** | BEAM WIDTH DEG -3/-6dB | MTG & WIRING | Ga | Ge | SHADING | Ke | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|
| CERAMIC DISK 200 KHz | 101.6 DIA | 101.6 DIA | 4.4/ 6.0 | 6000 | | | FRAME ONLY | .5 | Insufficient beam width |
| CERAMIC DISK 80 KHz | 123.0 DIA | 123.0 DIA | 9.8/ 12.2 | 6000 | | | FRAME ONLY | .5 | Insufficient beam width |
| MASS LOADED ELEMENT 80 KHz | 12.7 SQ | 30.1 X 30.1 | 25.0/ 35.0 | 6000 | 6-7 | 0 | 3 STEP ELE + FRAME | .144 | Requires development time |
| CERAMIC BLOCK 200 KHz | 2.5 X 7.6 X 22.9 | 13.7 X 22.9 | 28/38 X 16.8/23 | 6000 | 7-8 | 1-2 | 1 STEP + ELE OFFSET | .3 | Allows more shading possibilities with a reasonably wide beam pattern |
| CERAMIC BLO K 200 Hz | 2.5 X 7.6 X 22.9 | 17.5 X 22.9 | 29/31 X 16.8/23 | 6000 | 7-8 | 1-2 | 2 STEP + ELE OFFSET | .3 | Narrow beam width |

### 3.4.2 PROXIMITY SOUNDER TRADE OFF ANALYSIS

#### 3.4.2.1 Use of C-Tech FFC-2000 colour video sounder as test platform:

This sounder is considered due to the ready availability of comprehensive architectural data and the relative ease with which modifications may be implemented.

a) Two sounder channels are available, allowing for a forward looking primary intercept beam, and a downward looking beam to sense potential collision on water re-entry.

b) Transceivers can be independently modified to permit optimized operating frequency and sensitivity, although two IF channels are necessary for independent operation.

c) Modification of pulse parameters and inclusion of more sophisticated detection mechanism are possible via external hardware.

d) An integral data display exists for both sounder channels.

e) Record/playback ports enabling data storage via external audio cassette are included; however, this does not appear to be sufficient for the acoustic data analysis work.

#### 3.4.2.2 FFC-2000 limitations

##### 3.4.2.2.1 Data Rate

At the minimum possible basic range scale of 40 m (53.3 ms 2 way ranging), the unmodified sounder cycles at 211 pings/min (284.4 ms/ping) with the two channels selected on an either/or basis.

At a ship to ice speed of 10 knots (9.26 m/sec), this results in a closing rate of 2.63 m/ping for single channel sampling, or 5.27 m/ping if both are sampled. Both detection processing time and mechanical retraction time must be accommodated within time to impact at the minimum guaranteed detection range (Ref. para. 3.1.3) in the forward looking channel.

To provide multi-ping detection capability without making excessive demands on the retraction system, it is proposed to make the two sounder detection functions operate independently and to interpose additional pings. However, changing the basic display cycle rate would involve considerable software/hardware re-engineering.
Instead, the provision of independent IF channels and a TX pulse processing block would result in the following benefits:

a) Independent tailoring of detection functions for

the forward and downward looking channels.

b) The forward channel is not needed in the hide mode; however, it may be desirable to maintain downward detection continuously to detect deep welling ice.

c) Although the visual ice flux monitor data rate is unchanged, the actual detection data rate is readily improved to 71 ms if 4 pings per display cycle are used.

d) Transmit pulse duration and formats can be tailored to the individual detection functions.

#### 3.4.2.2.2 Bandwidth/Pulse Length

The basic FFC-2000 channel bandwidth of 4 KHz would allow a pulse length as short as 250 microseconds using the 1/T criterion for optimum noise bandwidth match rather than 2/T for pulse fidelity.

If a 1087 cc ice chunk is considered for convenience (approx. 1 Kg), this could be a 10.3 cm cube with 106 $cm^2$ area, or a 12.8 cm diameter sphere with 128 $cm^2$ acoustic cross section.

At 1500 m/s, 10.3 cm is traversed in 68.7 microseconds. A 250 microsecond pulse (or pulse sub-cell if pulse compression is used) with range extent of 37.5 cm is sub-optimal with respect to reverberation discrimination. For pulse length greater than the target length, reverberation background increases as a 10 log function of pulse length (5.6 dB in this instance), since reverberation comes from a range gate equal to half the pulse length.
However, reducing the pulse length to the target range dimension requires a higher electro-acoustic bandwidth of 14.6 KHz, with an attendant 10 log of bandwidth ratio increase in ambient noise level (also 5.6 dB).
The governing consideration would therefore be determined by which mechanism is the dominant limiting factor. However, the practical realizability of higher electro-acoustic bandwidth is a concern, particularly with respect to the transducer.

### 3.4.2.3 Alarm Signal Processing Requirements

#### 3.4.2.3.1 Noise Reduction Processing

##### 3.4.2.3.1.1 Sea State Noise

If some typical system parameters are assumed as a basis point, sea state noise level can be shown to be of little concern.
The echo to noise ratio for a 10.3 cm cube at 30 m, f=80KHz, is

$$E/N = SL - 2TL + TS - (NL-DI) = 64.4 \text{ dB}$$

for SL = 207 dB re 1 μPa @ 1m

TL = 20log(30m) + α = 30.2 dB

where α = .7 dB for 30m (24 dB/Km at 80 KHz from Urick' fig. 5.5)

$TS = TS_s + 10 \log k = (-12\ dB) + (-19.8\ dB) = -31.8dB$

where $TS_s$ is a reference target strength from C-Tech Report 813, "A Study Determining the Target Strength of Glacial Ice as a Function of Frequency", Graph 5.6, for a 1m cube at 45 incidence,
and k = (surface area of actual target/surface area of reference target)

$NL = NL_s + 10 \log BW = 66\ dB$

where $NL_s$ is the spectrum noise level for sea state 3 at 80 KHz, ca. 30 dB re 1μPa (from Urick' fig. 7.5)
BW is the system bandwidth of 4 KHz
DI is the transducer directivity index, estimated at 15.6 dB

3.4.2.3.1.2 Ice Breaking Noise

Noise levels are unknown, but it is expected that they will not be insignificant, and that the noise will contain strong impulse components. Since the noise will be largely incoherent and erratic, some form of integration processing should be used to improve the probability of a succesful field trial.

3.4.2.3.1.3 Reverberation

The dominant reverberation component in the forward channel is expected to be the surface reverberation from the hull. (Ref para. 3.1.2).
For the referenced detection statistics, it was shown that a detection index of 16 was required. Based on integrating 11 samples, an echo excess of .4 dB was determined for the calculated conditions.

3.4.2.3.1.4 Possible Solutions

3.4.2.3.1.4.1 Multi-Ping Averaging

Ranging time required for collection of 11 samples at 71.1 ms/ping is 782 ms, or 853 ms if the target is missed on the first ping. At 10 knots, this represents a distance of 7.9 m. To ensure that the target aligns with the averaging cells in successive pings, target speed compensation would be required to significantly better than (250 μs/782 ms), or .03%.
Even if ship's log derived compensation could be used to null the hull to water speed component, it is likely that the ice mass does not have zero water speed due to initial kinetic energy from the ice breaking, and due to sliding drag under the hull. These difficul-

ties argue against an effective solution. However, an m-out-of-n ping detection scheme could still be considered, since target alignment is not required.

3.4.2.3.1.4.2 **Phase Modulated Pulse Compression**

This may be considered as a "within ping" averaging technique; one possible execution consists of a phase modulated transmit pulse comprised of a number of sub-pulse cells. If 1 such cells of 250 μs are used and compressed to 250 μs on reception, the requirements of para. 3.1.2 could be met. This technique permits a relatively simple realization of the modulated transmit pulse compared to frequency modulated pulse compression. Range sidelobes in the compressed pulse would be minimized by use of a "Barker code".

A disadvantage of this scheme is the need for fully coherent processing of the received pulse, since the summation of the terms is proportional to the sines of their relative phases.
Sensitivity to uncompensated Doppler is therefore low for small shifts, but escalates rapidly (ref. para. 3.4.2.3.1.4.5).
The need for coherence maintaining relationships between water frequency, intermediate frequency, and pulse cell period also restricts the flexibility of this processing method.

3.4.2.3.1.4.2.1 **Implementation**

The transmit pulse consists of n cells, each of the duration of the compressed pulse. The cells contain energy either at reference phase, or its inverse, according to the code sequence.
On reception, pulse compression processing must occur at a point where phase information is preserved; optimum location is after gain normalization and before envelope extraction. The received pulse requires a matched auto correlation filter. This can be realized by passing the signal through a delay line with taps at increments of the pulse cell length; the tap outputs are then phased according to the selected phase code and summed.

3.4.2.3.1.4.3 **Frequency Modulated Pulse Compression**

An alternative technique for pulse compression consists of generating a linear FM sweep over the transmit pulse interval, and passing the received signal through a dispersive delay line which is the matched filter to the transmitted waveform.
For the assumption of a 4kHz chirp in a 2.75 ms pulse duration, the pulse compression ratio CR = Tδf, or 11 as in the phase modulated example; and the compressed pulse length τ=1/δf

results in the same 250μs.
This method has a significant advantage in its relative insensitivity, for large compression ratios, to uncompensated Doppler shift; the output power loss is proportioned to td/T, or a loss of 6td/τ range bins as they slide outside the receiver passband.
For a water frequency of 80kHz, this results in a power loss of 1.37%/knot of uncompensated Doppler shift (ref. para. 3.4.2.3.1.4.5). The correlation gain of the compressed pulse is 10 log CR.

3.4.2.3.1.4.4 Array Processing

The magnitude of the reverberation problem increases as a 10 log function of beam width. It is therefore possible to conceive a multi-beam solution where n beams of 1/nth of the overall beamwidth are used, providing a 10 log n advantage in reverberation seen by each beam. Individual signal processing would be required for each beam; the outputs of each detector are polled such that any beam can trigger the alarm function.
Note that, since the available proximity transducer space is limited, the operating frequency must be raised; both to produce narrow beamwidths, and to produce each beam in less space.
Based on its attendant complexity, and on the decrease in ice target strength vs. operating frequency, this approach does not appear optimal.

3.4.2.3.1.4.5 Fixed Echo Suppression

Since the forward looking sounder beam must approximately graze the hull to detect ice sliding along the hull, it is expected that a significant fixed echo return profile could exist from ping to ping. The target echo could be masked by this fixed component, in which case simple thresholding would be an unsatisfactory solution.
It is possible to store a reference echo profile of the hull return component and perform a subtraction of this profile from the return energy for each ping, thus cancelling its contribution. Large variance in the return from the main hull features is not expected because of their fixed relationship to the transducer; the degree of variance of the "fixed" return component will determine the relative target size which can be discriminated against the background.
The reference memory should be comprised of an average of the data from n recent pings, or n of every mth ping, to provide automatic compensation of slowly varying acoustic conditions.
A speed dependent term should be introduced to prevent the memory from swallowing targets if

the speed is too low.

3.4.2.3.1.4.5.1 **Initialization Considerations**

A hull profile must be built up over a number of pings and stored in a reference memory to allow the fixed echo suppression mechanism to function.

While a period of several pings of blindness may be an acceptable risk when moving from peek to seek mode, the system should be fully functional when entering peek mode in normal hide to peek cycling, as no advance warning of impending collision with sliding ice is practical.

Since the suppression mechanism cannot function effectively until the reference profile is stored, and since the two forward-looking operational modes will see a different fixed profile, a possible solution lies in the provision of separate reference images for both peek and seek modes, with a fairly rapid transition from peek to seek extension.

A possible initialization sequence for the two memory solution is given in figure 1.

3.4.2.3.1.4.6 **Own Doppler Correction**

A Doppler shift of (2 /c)f will be experienced in the forward detection channel; for 10 knots, 1500m/s, and 80KHz, this results in a shift of 987.73 Hz.

For a signal centred in a nominal noise matched 4 KHz band, this represents a loss of an upper 49.4% of a sideband.

In addition, the performance of any coherent processing scheme, such as pulse compression, would be affected.

For the specific example of an 11 X 250μs cell pulse, this results in a phase shift of 970° (987.73 Hz X 250μs X 11 X 360°) over the pulse.

If the shift is held to 45°, thus producing 3dB droop across the summation terms of the pulse, correction of Doppler shift to within .020 knot is required.

This could be accomplished by shifting the receive local oscillator frequency in proportion to a ship's log derived speed correction.

3.4.2.3.1.4.7 **Range Gating**

To reduce the possibility of detection outside the danger area due to beam spreading, it is proposed to range gate the forward detection zone. (For a range limit of 30m at 10 knots, a 25° horizontal beam would spread to 13m).

In addition, there is little point in permitting retraction attempts on small ice pieces detected too close to successfully avoid.

Both limits of the range gate window could be made speed dependent via a ship's log derived signal.

3.4.2.3.2 **Main Sonar Software Impact**

The main sonar operational software must be made compatible with the hide-peek-seek operational modes to avoid the need for continual operator intervention. Specifically, this can be achieved by

a) removing any software time limit for hoist response to a command

b) modifying the software to abort the current sonar cycle in response to a retraction signal and automatically resuming operation with a new ping cycle in response to a full extension.

## REFERENCE MEMORY INITIALIZATION SEQUENCE

## 3.4.4 ICE FLUX MONITORING AND ACOUSTIC DATA COLLECTION

### 3.4.4.1 Ice Flux Monitoring

The FFC-2000 sounder display can be used as the ice flux monitor. Either 40 m or 20 m range display can be selected with 256 pixel resolution full screen, or 128 pixel/channel if both are displayed. An "A" scope presentation is also available. The screen update rate is 284.4 ms for a single channel display, or 568.8 ms per channel if both channels are selected. This is probably adequate for receiver dynamic range monitoring and control set-up purposes, as well as operator feedback of operating conditions.

### 3.4.4.2 Data Collection Requirements/Data Analysis Phase

The data analysis phase of the project must be supported by an adequate quantity and quality of raw field data. The requirements have been defined as:

a) Obtain and analyze a modest amount of acoustic data which would allow one to qualify the acoustic environment of the transducer operation, both for the ice pieces detector and for the primary transducer. (Proposal, CTL Report No. 973, section 4.1).

b) To gather sufficient data and insight into the ship's self generated noise, it is necessary to measure the actual noise level in the water below the ship. To this end, it is proposed: to use the same sonar as for the previous trials; to include proximity sensing devices on the sonar head.
This approach should allow for the gathering of sufficient information needed to characterize the noise environment, thus providing an opportunity to gather a suitable data base for a valid decision on the detection capability in ice of the sonar sensor. In the process it should also be possible to gather information on the quantity and the size of ice blocks passing under the hull.
(TDC proposed work statement introduction, March 1988 revision)

Accordingly, data should be extracted from both the proposed proximity sounders and from the main sonar to allow analysis of the following:

a) noise background characteristics, statistics and speed dependence, in both open water and ice breaking operations, for sea noise, ship generated noise, and surface and volume reverberation.
b) Quantity and echo levels of ice blocks passing under the hull.
c) Detection range and statistics.

While at least some data taking and analysis must be done on board for operational verification and back-up purposes, it is proposed to provide primary data storage capability to allow additional laboratory analysis for the following reasons:

a) Better data capture, with more data recorded in real time; critical events may otherwise be missed.
b) Higher data integrity due to reduction of human error factor.
c) Subsequent verification is possible.

Although a minimalist solution for on-board measurement/-analysis could be an oscilloscope and manual note taking, it is felt that provision of a suitable data analysis system should be considered to permit more data crunching power and reduced probability of human error in the detailed analysis phase.

The main sonar was previously provided with a data collection interface suitable for magnetic tape recording, CTL P/N 12918, and was also characterized in CTL Report No. 851 (note recalibration requirement per section 3.2.1.1).

The proximity sounders must also be acoustically and electrically characterized for correlation with collected data.

3.4.4.2.1 FFC-2000 Limitations

The data analysis phase of the project must be supported by an adequate quantity and quality of raw field data.
Although the FFC-2000, when supported by a stereo audio cassette recorder, can provide archival storage capability, the following limitations apply:

a) One channel is dedicated as a fixed format control track for record/playback synchronization and is not readily modified.
b) The available data channel is satisfactory for replay purposes via the cassette port, IF amplifier, and video display of an FFC-2000.
While estimates of ice flux density and range extent may be practical from observation of the replay data, absolute target strength, reverberation, and noise levels would be difficult to extract without complete characterization of a number of analog control curves[1], in addition to manual field logging of control positions and ship's speed vs. tape count for subsequent correlation with observed data on analysis.
Supplementary data would be difficult to add in this format, except for a superimposed alarm tick.
c) Simultaneous recording of data at various points in the processing chain, or recording data from both proximity sounders would not be possible.

---

[1] STC,
STC level,
sensitivity,
cassette recorder data channel sensitivity control setting
sensitivity setting on playback
ship's speed

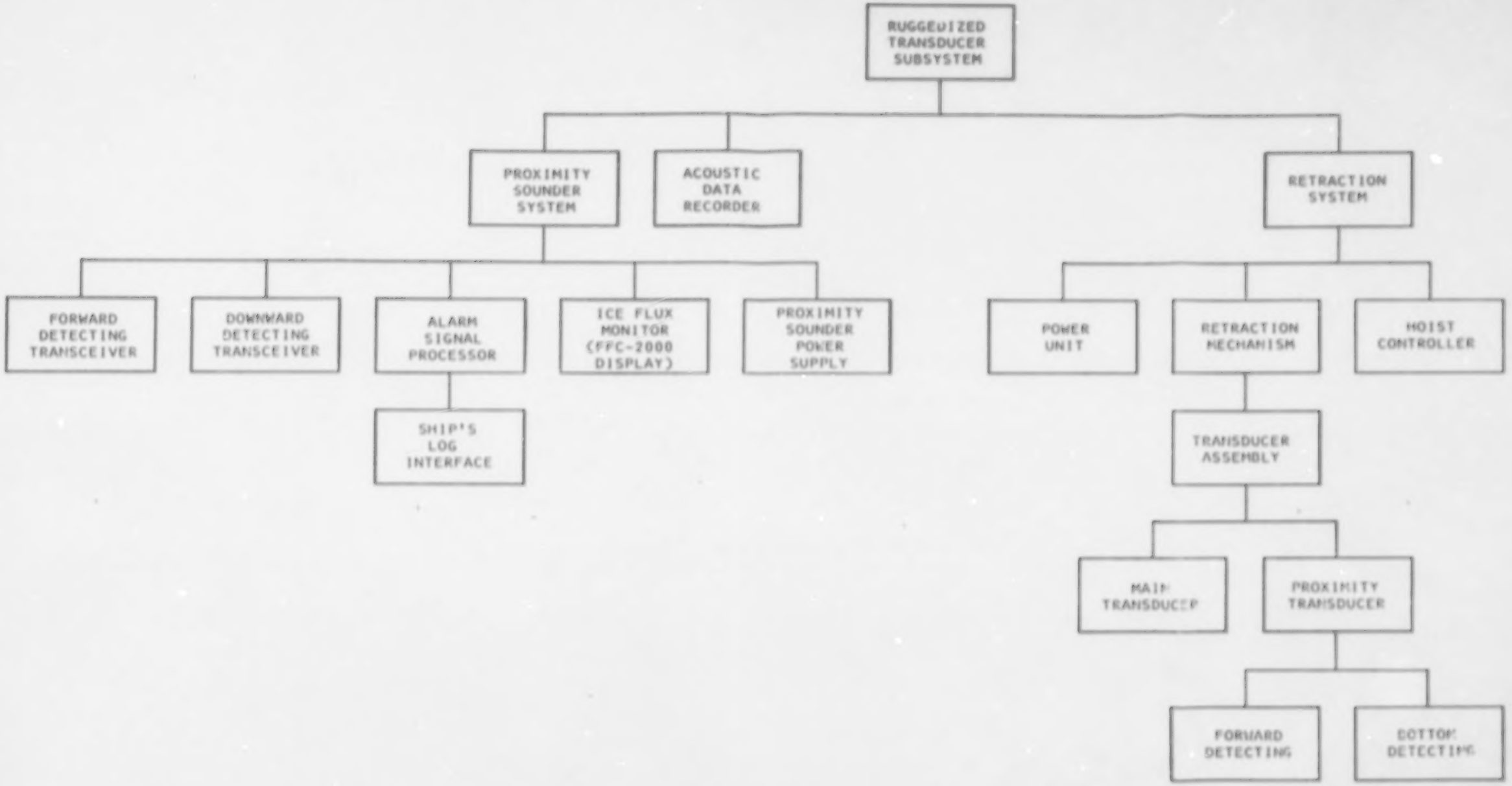
d) Available cassette tapes exhibit varying degrees of time dependent amplitude compression at the 10 KHz audio carrier frequency, compounding the problem of measurement accuracy.
This limitation could be reduced significantly by using a good 1/4 inch tape reel-to-reel audio recorder instead of the Philips cassette format.

3.4.4.2.2 Alternative solution

If it is assumed that the above limitations do not allow an adequate solution, a multi-channel instrumentation FM tape recorder could be procured or rented to allow high quality recording of all relevant return data, complete with direct recording of attendant control analog position data and voice-over commentary. Recorders are available in both 1/4 inch reel-to-reel tape format and VHS video cassette format; a typical rental price is $ 2300-2400 (CDN) per month for a 14 channel RACAL Store 14 DS recorder.
The recorder would need to be available for the design verification, system integration, data collection and data analysis phases (at least 6 months).

1. Principles of Underwater Sound - Robert J. Urick

2. Principles of Modern Radar - Jerry L. Eaves and Edward K. Reedy




Ice Detection Sonar
Ruggedized Transducer Subsystem
Block Diagram

| CTL REPORT NO. | 1064 |
|---|---|
| REV. A | SHEET 36 |

# APPENDIX C

CTL REPORT NO. 1075,
"SYSTEM DESIGN SPECIFICATION FOR A
RUGGEDIZED TRANSDUCER SUBSYSTEM FOR
ICE HAZARD DETECTION SONAR"

| REVISIONS | | | |
|---|---|---|---|
| LTR | DESCRIPTION | DATE | APPROVED |
| A | General update; added optical communications link. Retyped. | 27-09-89 | RWB |

REPLACES REV - WITH CHANGE

| REV | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHEET | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |

**C-TECH LTD.**

CORNWALL, ONTARIO K6H 6N7

# SYSTEM DESIGN SPECIFICATION FOR A RUGGEDIZED TRANSDUCER SUBSYSTEM FOR ICE HAZARD DETECTION SONAR

| | | |
|---|---|---|
| PREPARED | 27-09-89 | RWB |
| CHECKED | 89-10-25 | |
| APPROVED | 89-11-09 | |

REPORT NO. 1075

SHEET 1 OF 18

C-TSS7

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# SYSTEM DESIGN SPECIFICATION FOR A RUGGEDIZED TRANSDUCER SUBSYSTEM FOR ICE HAZARD DETECTION SONAR

## 1.0 SCOPE

This report defines the system design specifications for a ruggedised transducer subsystem for an ice hazard detection sonar originally proposed in C-Tech Ltd. Report No. 975 and supplements Report No. 1064, "Requirements for a Ruggedised Transducer Subsystem for Ice Hazard Detection Sonar".
In view of the experimental nature of the program, the specifications quoted should be considered as nominal targets where quantitative data are provided.

## 2.0 MECHANICAL SPECIFICATIONS

### 2.1 Retraction Mechanism

The requirements and specifications of the retraction mechanism are detailed in C-Tech Ltd. Report No. 1069, "Statement of Work - Retraction Mechanism Subsystem for Ice Hazard Detection Sonar".

### 2.2 Transducer Assembly

This sub-assembly must be ruggedized to withstand impact of ice fragments of up to 1 Kg mass at a speed of 18 Knots; as well as the acceleration, shock and vibration imparted by the retraction mechanism cycling and ship ice breaking operation.
In the seek and peek modes, the transducer must have frangible points in line with the ship's bottom hull. The frangible points must shear without bending the main shaft beyond its elastic limit.
Furthermore, the bottom of the transducer should be shaped to promote upward deflection on impact with ice in the peek mode.
A proximity transducer compartment flood sensor should be provided and wired in parallel with the main sonar transducer flood sensor.

## 3.0 ELECTROACOUSTIC SPECIFICATIONS

The electroacoustic specifications of the forward and downward looking proximity sounders are defined in Table 3.0.

## 4.0 SYSTEM BLOCK DIAGRAM DESCRIPTION

The system block diagram is presented in figure 4.0; its constituent block functions are described below:

### 4.1 Proximity Transceivers

These sub-units provide the following functions for each detection channel unless otherwise noted:

## TABLE 3.0 SYSTEM DESIGN SPECIFICATION - ELECTROACOUSTIC

| PARAMETER | PROXIMITY SOUNDERS PSD0600-L00S1A0 | | DOOR600 L00S1A | CONDITIONS |
|---|---|---|---|---|
| BASIC DETECTION STATISTICS<br>ROC CURVE<br>P(D)<br>P(Fa) | (condition 1)<br>d=16<br>90%<br>0.5% | | (condition 2)<br>d=16<br>90%<br>0.02% | 1. Target strength = -12 dB @ 80 Khz, Range = 20 m<br>2. Target strength = -4 dB @ 285 Khz, Range = 7 m<br>m ranging cycles with false alarm(s) in n cycles |
| PROCESSED DETECTION STATISTICS | m=5, n=8 | m=6, n=8 | | |
| P'(D)<br>P'(Fa) | 99.5%<br>1 in 1.9 hrs | 96.3%<br>1 in 55.6 hrs | 99.9%<br>1 in 36.8 hrs | |
| OPERATING FREQUENCY | 80 Khz | | 285 Khz | |
| BANDWIDTH | 4 Khz | | 4 Khz | |
| BEAMWIDTH | 25° H, 10° V | | 12° Horiz/Vert,<br>12° athwart | |
| ALIGNMENT | 5° depression | | 8° Forward of Vertical | |
| SOURCE LEVEL | 207 dB re 1 uPa/m | | 197 dB re 1 uPa/m | |
| PULSE LENGTH | 2.75 ms | | 250 ms | downward and forward looking pulses not simultaneously |
| PULSE REPETITION RATE | 71 ms | | 71 ms | average |
| DETECTION RANGE | 4.13 m - 20 m | | 0.38 m - 20 m | |
| TRANSDUCER<br>TRANSMITTING RESPONSE<br>RECEIVING RESPONSE (95 OHM) | 184 dB re 1 uPa/m/V<br>-184 dB re 1 V/uPa | | 188 dB re 1 uPa/m/V<br>-194 dB re 1 V/uPa | include cable matching and transmission loss |
| TRANSMITTER<br>POWER | ca. 150 W | | ca. 7.5 W | specified transmitting response |
| RECEIVER<br>DETECTION SENSITIVITY (95 OHM) | THC to -77 dB//20 m adjustable ± 6 dB | | THC to -77 dB// m adjustable ± 6 dB | specified receiving response and detection statistics |
| ALARM PROCESSING<br>OWN DOPPLER CORRECTION | 12 Knot | | ——— | compensate on receive |
| PULSE COMPRESSION | 20 | | ——— | compression ratio 11 |
| FIXED ECHO SUPPRESSION | profile subtraction coefficient unity | | ——— | must not suppress target at minimum speed |
| RANGE GATE<br>M-OUT-OF-N FILTER | 4.13 m - 20 m<br>m=5, n=8 | | 0.38 m - 3 m<br>m=3, n=4 | m ranging cycles with false alarm(s) in n cycles |
| ALARM DISTANCE | ship's speed, m/s<br>x<br>transaction time =<br>0.13 s,<br>≥ 4.13 m | | immediate | R1 is a safety margin, ca. 0.7 m * |
| ALARM TO DETECTION DELAY | (alarm distance + R1)/s<br>ship's speed, m/s | | 4 ranging cycles in wide mode | R2 is a safety margin, ca. 3 m * |
| BEARING ERROR | <5 degrees below a Knots<br><2 degrees for reverse | | | provide manual override capability<br>e is an accuracy margin, ca. 0.3 Knots * |

* TBR in detail design phase

| REV | DESCRIPTION | DATE |
|---|---|---|
| A | DRAFT 1 | |

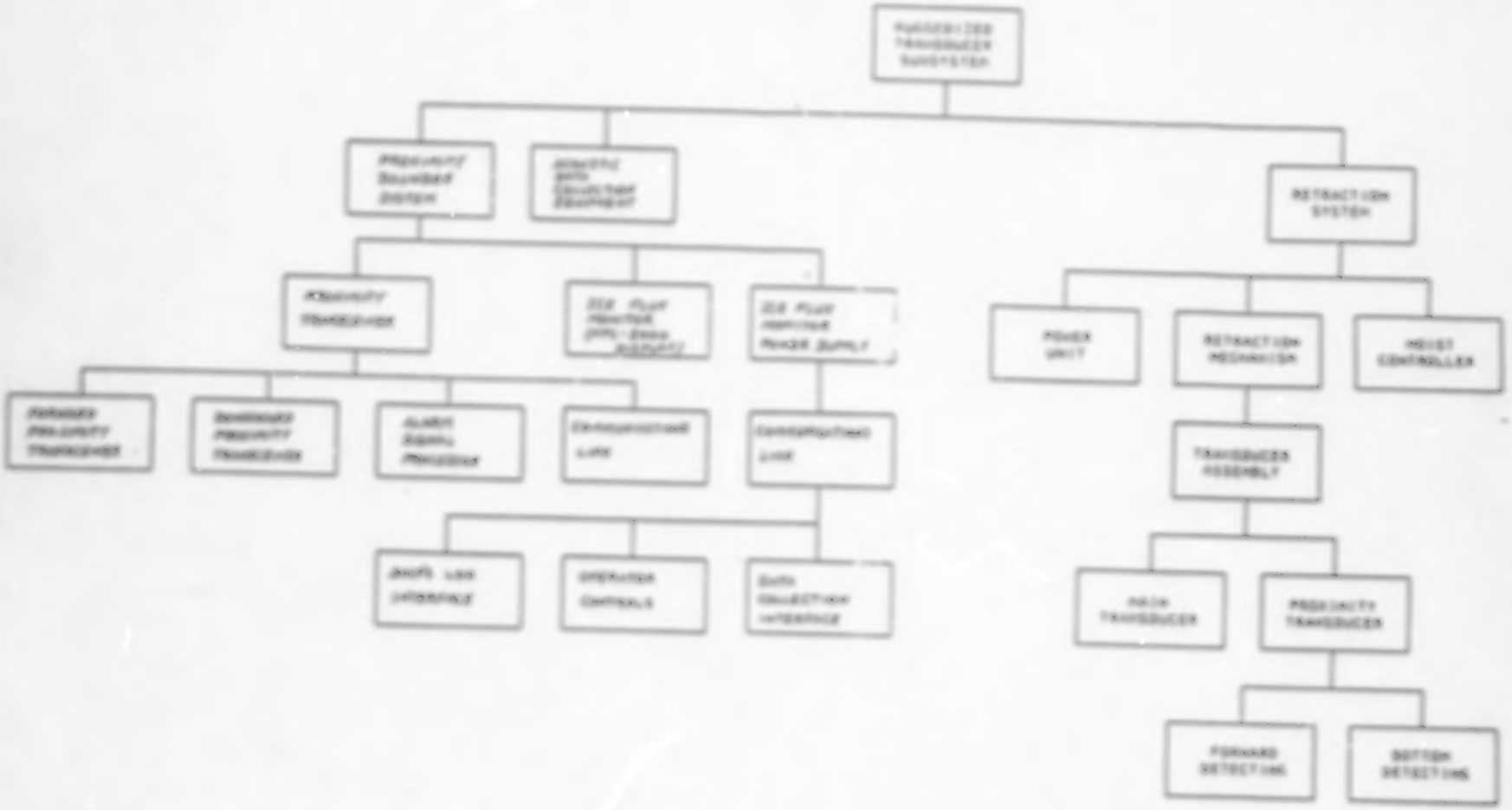

Figure 4.0

Ice Detection Sonar
Suggested Transducer Subsystem
Block Diagram

| CTL REPORT NO. 1073 | |
|---|---|
| REV. A | SHEET 6 |

4.1.1 FM Sweep Generator (forward detection channel)
Produces a linear 78 kHz - 82 kHz sweep during the 2.75 ms transmit pulse gate.

4.1.2 Transmitter
Generates the required power level to drive the transducer via the tuning and matching transformer(s).

4.1.3 Tuning and Matching
Provides transmitter tuning and matches the transmitter and receiver ports to the transducer cable impedance.

4.1.4 Receiver Front End
Provides bandlimited preamplification, gain normalisation, and conversion to intermediate frequency for the return signals.

4.1.5 Own Doppler Nullifier (forward detection channel)
Controls local oscillator frequency in response to speed data from Ship's Log Interface to cancel ship's self generated Doppler.

4.1.6 TVG Control
Generates the time varying gain normalization control curve for the Receiver Front End when keyed by the TX Pulse Processor.

4.1.7 I.F. Channel
a) provides remaining post-conversion return signal amplification.
b) provides dominant signal bandlimiting.
c) provides a bandlimited gain-normalized IF signal for the RX Pulse Processor.
d) provides a detected analog envelope output for the data recorder.

4.1.8 Sensitivity Control
a) complements the TVG control and/or alarm detection threshold setting to set optimum overall operating point.
b) a proportional analog output will be supplied for the data collection recorder.

4.2 Alarm Signal Processor

Provides transmit signal control, receive signal detection enhancement, range gating, alarm processing, correction controller interface, and ship's log interface functions as detailed below:

4.2.1 TX Pulse Processor
a) triggers from either "LF TX" or "HF TX" pulses from PPC-2000 main unit occurring on an either/or basis

at ca. 284 ms intervals.

b) interpolates pulses to produce simultaneous transmissions for forward and downward sounders to produce an average repetition interval of ca. 71 ms.

c) generates a 2.75 ms forward sounder pulse gate and a 250 us downward sounder pulse gate.

d) provides a 2.75 ms transmit reference pulse for the data collection recorder.

4.2.2 RX Pulse Processor (forward detection channel)

a) accepts a bandlimited gain-normalized IF signal.

b) performs FM pulse compression to transform incoming 4 kHz swept 2.75 ms pulse energy to 250 us compressed pulse.

c) extracts the compressed return signal envelope with a ping to ping amplitude variation within 1 dB.

d) provides compressed signal output for fixed echo suppression.

e) provides an analog output of the compressed signal envelope for the data collection recorder and the ice flux monitor.

4.2.3 Fixed Echo Suppression (forward detection channel)

a) digitizes and stores a reference profile of the compressed signal fixed echo return from the hull and hull features, if any, for each of the two forward looking transducer positions; i.e. peek and seek modes.

b) generates each reference profile from the average of a large number of returns, either from n consecutive pings or from n pings selected every mth ping.

c) provides environmental adaptation capability, either via periodic updating of the reference profile in a non-intrusive manner, or via continuous averaging. The update mechanism must not swallow the target when the ship is moving slowly or is at rest. A compatible initialization sequence, such as that suggested in CTL report 1064, shall be implemented. The reference profiles are preserved during normal operating retraction cycles to allow immediate operation upon subsequent extension.

d) selects, scales, and subtracts the reference profile appropriate to the operating mode from the incoming data in real time. Scale factor selection should be variable over the range 0 to 2x magnification and shall include the options 0 and 1x.

e) provides an echo suppressed output for range gating.

f) provides an analog echo suppressed output for the data collection recorder and the ice flux monitor.

4.2.4 Range Gate

Provides range gating within the limits of 4.125 m to 20 m on the forward detection channel, and between 0.375 m to 7 m in the downward detection channel.

4.2.5 M-out-of-N Discriminator

a) requires target returns to exceed a presettable detection threshold on any m of n consecutive echo ranging cycles to qualify as a valid alarm condition.

b) for the forward detection channel, m is presettable to 5 or 6 where n = 8.

c) for the downward detection channel, m = 3 and n = 4.

4.2.6 Alarm Interface

a) accepts ship's log interface speed data and hoist controller status feedback in the form of contact closures for each of the operational modes; i.e. rest, clear, hide, peek and seek.

b) on the forward detection channel, generates an alarm hold-off delay [using speed data from the ship's log interface] until a threat reaches a distance set by the equation:

$$\text{ALARM DELAY DISTANCE (m)} = \text{SHIP'S SPEED (m/s)} \times (\text{RETRACTION TIME(s)} + k_s\text{(s)})$$

where $k_s$ is a safety factor to allow for detection and response time (ca. 0.7s, to be confirmed in detail design phase) or 4.125 m, whichever is greater.

c) selects downward detection channel in hide, peek and seek modes, and forward detection channel with appropriate reference memory in peek and seek modes.

d) determines alarm to transducer extension delay time for the forward channel set by the equation:

$$\text{EXTENSION DELAY(s)} = \frac{\text{ALARM GATE DISTANCE (m)} + k\text{ (m)}}{\text{SHIP'S SPEED (m/s)}}$$

where k is a safety margin (ca. 3 m, to be confirmed in detail design phase)

e) forces retraction for ship's speeds less than ca. 0.5 knot (to be confirmed in detail design phase) or for reverse motion unless a manual override signal exists; manual override is self-resetting when ship's speed again moves outside the guard band.

f) provides pilot light indication for each operating mode.

g) provides system power pilot and position request contact closures for the hoist controller.

h) provides visual indication of alarm status for each channel.

4.2.7 Ship's Log Interface

a) accepts ship's log data and generates compatible speed data for the alarm processor and forward detection channel Geo Doppler Multifier functions.

b) provides an 18 knot full scale analog DC output for the data collection recorder.

4.3 Power

The Proximity Transceiver and Alarm Signal Processor functions are self-powered from the ship's 115 V AC mains supply.

4.4 Ice Flow Monitor

4.4.1 FPC-2000 Main Unit

a) serves as the platform for the proximity sounder controls and data analysis interface.

b) provides a color CRT scrolling chart display with a 28 dB dynamic range. Presentation can be either proximity sounder full screen with an update rate of ca. 284 ms (every 4th sounding), or both channels half screen with an interleaved update rate of ca. 568 ms (every 8th sounding). An "A" scope presentation may also be selected.

c) basic range scaling is 40 m; expanded scaling is available in single channel mode.

Functions used in this sub-system are:

4.4.1.2 Sonrow Selector

Provides selection of any one or a pair of the following signals for display presentation:

a) forward detection channel compressed return pulse.

b) forward detection channel fixed-echo-suppressed return pulse.

c) downward detection channel return pulse.

4.4.1.3 Video Processing and Video Display

Provides the ice flow monitor display function.

4.4.1.4 Control Processor

Controls basic transmit/receive and display timing.

4.4.1.5 Power Conversion

Converts 12-32 VDC input power to supply main unit DC requirements.

4.5 Ice Flow Monitor Power Supply

This external supply converts ship's 115 V AC mains power to 24-28 V DC 6 A for the main unit power converter.

## 4.6 Acoustic Data Collection Equipment

### 4.6.1 Multichannel Instrumentation Recorder

a) 115 V AC operation
b) Bandwidth: DC - 5 kHz min.
c) Dynamic Range: 0-5 V, noise -40 dB
d) 12 channels to record the following data:

1. sounder TX pulse
2. forward sounder sensitivity control
3. forward return signal, unprocessed
4. forward return signal, compressed
5. forward return signal, fixed echo suppressed
6. downward sounder sensitivity control
7. downward sounder return
8. transducer shaft position
9. ship's speed
10. main sonar "Audio & Recorder Interface Unit" Data output
11. main sonar "Audio & Recorder Interface Unit" Reference Clock output
12. voice annotation

### 4.6.2 Video Cassette Recorder

a) 115 V AC operation
b) NTSC format
c) records main sonar video data and control data screen

### 4.6.3 Video Monitor

a) 115 V AC operation
b) NTSC composite video input
c) allows verification of VCR recording; the monitor is not essential but is recommended.

### 4.6.4 Oscilloscope

a) dual channel
b) digital storage capability, 1 MHz sampling minimum
c) allows signal verification and limited on-board sea trial data taking and analysis

### 4.6.5 Support Items

#### 4.6.5.1 Recording Media

##### 4.6.5.1.1 Magnetic Tape for Instrumentation Recorder

to support a minimum of 48 hrs. recording time at the specified bandwidth.

##### 4.6.5.1.2 Video Cassette

to support a minimum of 48 hrs. recording time in the "standard play" mode

4.6.5.2 Cabling
all necessary cabling to support above items

4.6.7 Availability Period
approximately 6 months for all data collection equipment, including system integration, sea trial, and data analysis phases.

## 4.7 Retraction System

This sub-system is designed to provide a mechanism for accessing the underwater environment, by lowering the transducer assembly below the bottom of the ship.
The retraction system resides in the Sonar Compartment (lower part of the ship).

4.7.1 Power Unit
Supplies the actuating power to the retraction mechanism.

4.7.2 Retraction Mechanism
This sub-unit interfaces with the transducer assembly and the ship. It is mounted directly on the flange of the ship's gate valve. Its main function is to extend the transducer into the water below the ship when in use, and retract the transducer within a tube above the ship's gate valve when not in use.
The retraction mechanism is capable of cycling from rest to various positions as dictated by the Hoist Controller in accordance with the operating modes.

4.7.3 Hoist Controller
This sub-unit is mounted on the retraction mechanism and responds to signals from the Alarm Processor Unit to activate the Power Unit and control the retraction mechanism motion.

4.7.4 Transducer Assembly
This assembly is comprised of three transducer units; main, forward proximity and downward proximity. The transducer assembly is mounted to the retraction mechanism's transducer support flange with its cables passing through the support. A water tight seal is fitted at the transducer flange interface.

4.7.4.1 Main Transducer
This ruggedized omnidirectional transducer interfaces with the main sonar system to provide the principal long range detection capability. The main transducer occupies the top main body section of the transducer assembly.

4.7.4.2 Forward Proximity Transducer

This transducer consists of a forward looking directional array tilted downward approximately half its vertical beam width and mounted in an isolated housing directly below the main transducer. Its main purpose is to detect ice coming from the front of the ship.

A combination of steel rail and plastic sheeting or a dome provides protection from damage by small ice fragments.

The transducer, when tuned and matched to the interconnecting cable, should have a composite transmit/-receive transfer function variation within 1 dB over the 78-82 KHz band.

4.7.4.3 Downward Proximity Transducer

This transducer is a downward looking directional type mounted in the housing with the forward proximity transducer behind an acoustically transparent protective window. Its main purpose is to detect ice directly below the ship.

The transducer, when tuned and matched to the interconnecting cable, should have a composite transmit/-receive transfer function variation within 1 dB over the 203-207 KHz band.

## 5.0 SUB-SYSTEM INTERFACES

### 5.1 Electrical

#### 5.1.1 Sounder Transducers to Proximity Transceivers

a) interconnect via low loss controlled impedance twinaxial shielded cables; length to be confirmed
b) tune and match transducers to cable impedance
c) tune and match transceivers to cable impedance

#### 5.1.2 Hoist Controller to Proximity Transceiver Alarm Processor

a) Alarm Processor provides contact closures for the following control signals using a single isolated common:

1. system power pilot
2. rest mode
3. clear mode
4. hide mode
5. peek mode
6. seek mode

Rest mode will be the power off default condition.

b) Hoist Controller provides contact closures for the following status feedback signals using a single isolated common:

1. rest mode

2. clear mode
3. hide mode
4. peek mode
5. seek mode
6. system ready (initialization complete)

c) Interface signal levels shall not exceed 28 V DC
d) The Hoist Controller also provides a DC analog signal representing hoist position to an isolated communications link input port (ref. 5.1.10.2.t)

5.1.3 Proximity Transceiver Alarm Processor to Main Sonar

a) interface shall be compatible with main sonar connector 2A4J5 as defined below:

| | |
|---|---|
| pin 1 | 12 V DC relay power, 1/16 A fuse, non-isolated |
| pin 2 | "raise" open collector output, active low (system shutdown request) |
| pin 3 | "lower" open collector output, active low (system activate request) |
| pin 5 | "up" contact closure sense, active low, rest mode |
| pin 6 | "down" contact closure sense, active low, seek mode |
| pin 7 | common |

5.1.4 Ship's Log to Ice Flux Monitor

A compatible interface will be provided to allow access to ship's speed log data (speed log port specifications must be supplied).

5.1.5 Main Sonar Transducer to Main Sonar

a) the main sonar transducer will remain electrically compatible with the existing main sonar T/R unit transducer connectors 2A4J1, and 2A4J3.
b) the transducer cables should be provided with additional connectoring located at the retraction mechanism to permit cable replacement in the event of damage if possible.

5.1.6 Ship's Power to Subsystem Units

The following subsystem units will be compatible with 115 V AC 60Hz ship's power supply:
a) ice flux monitor power supply
b) proximity transceiver
c) acoustic data collection equipment
d) retraction system controller

The retraction system will be compatible with 360 V AC 3 phase 60 Hz ship's power supply.

5.1.7 Data Collection Interfaces

5.1.7.1 Main Sonar "Audio & Recorder Interface Unit 12918" to Data Collection Recorder

a) "Signal" front panel BNC connector, 1 kHz nominal, 5 V p-p max
b) "Reference Clock" front panel BNC connector, 750 Hz 5 V p-p

5.1.7.2 Ice Flux Monitor to Data Collection Recorder

all data collection signal outputs defined in para. 4.5.1 will be available via Ice Flux Monitor front panel BNC connectors.

5.1.7.3 Main Sonar Composite Video Interface to Video Cassette Recorder

composite video output, Control Indicator rear panel RCA connector, NTSC non-interlaced, 1 V p-p into 75 ohms

5.1.8 Data Analysis Interface

a) provide two front panel BNC connectors for the data verification and analysis oscilloscope (ref. para. 4.5.4).
b) provide selector switching to allow independent access to any of the data collection recorder signal outputs (ref. para. 4.5.1) for each connector.

5.1.9 Subsystem Operator Interface

5.1.9.1 Indicators

a) Ice Flux Monitor (ref. para 4.3.1 b)
b) Operational Status
provide LED indicators of the designated colors on the front panel of the Ice Flux Monitor for the following:

| Request | | Status | |
|---|---|---|---|
| Rest | - orange | Rest | - green |
| Clear | - orange | Clear | - green |
| Hide | - orange | Hide | - green |
| Peek | - orange | Peek | - green |
| Seek | - orange | Seek | - green |

Reverse/Low Speed - red

Reverse/Low Speed Manual Override - orange

Forward Alarm - red
Downward Alarm - red
(alarm indicators persist until all clear condition and are unaffected by alarm inhibit switches)

Communications Fault - Red

Hazardous Mode - Red (flashes when test mode controls inhibit normal operation)

5.1.9.2 Operator Controls

a) the main system Control Indicator Hoist Raise/-Lower function will assume the master system shutdown/system activate function
b) a low speed retract namual override switch will be provided on the Ice Flux Monitor; this function will self reset when the ship's speed again moves outside the guard window
c) a fixed echo suppression update inhibit switch will be provided on the Ice Flux Monitor
d) proximity sounder control functions will be modified as applicable in the detail design phase
e) main sonar controls will remain unchanged
f) a manual hoist retract switch will be provided on the Alarm Processor

5.1.9.3 Test Mode Controls

The following functions should be available as protected switches to facilitate system testing:

a) defeat transmit
b) inhibit forward alarm
c) inhibit downward alarm
d) forward alarm hold off delay defeat
e) forward alarm to extension delay defeat
f) clear existing alarm (momentary)

In addition, the speed log interface should assume a zero speed default condition in the absence of a speed log input.

5.1.10 Communications Link

A ca. 200 m fibre optic sommunications link shall provide intrinsically safe two-way communication between the Ice Flux Monitor, located in the operations area, and the Proximity Transceiver, located in the sonar compartment.

5.1.10.1 Downlink Signals

The following signals will be downlinked:

a) forward sensitivity control data
b) downward sensitivity control data
c) speed log data
d) forward m-of-n m=5/m=6 select switch status
e) clear low speed/reverse retract switch status
f) fixed echo suppression update enable switch status
g) manual retract switch status

h) forward compressed return/fixed echo profile select switch status
i) master TX key pulse (from ice flux monitor)
j) uplink communications ok status
k) transmit defeat switch status
l) forward alarm defeat switch status
m) downward alarm switch status
n) forward alarm hold-off delay defeat switch status
o) forward alarm to extension delay defeat switch status
p) clear existing alarm switch status

5.1.10.2 Uplink Signals

The following signals shall be uplinked:

a) forward return (unprocessed) data
b) forward return (compressed) /fixed echo profile data
c) forward return (fixed echo suppressed) data
d) downward return data
e) rest request
f) clear request
g) hide request
h) peek request
i) seek request
j) forward TX marker pulse
k) downlink communications ok status
l) rest status
m) clear status
n) hide status
o) peek status
p) seek status
q) forward alarm status
r) downward alarm status
s) low speed/reverse status
t) hoist position

5.1.11 Main Sonar Software Interface Modification

The main sonar operational software must be made compatible with the hide-peek-seek operational modes to avoid the need for continual operator intervention. Specifically, this can be achieved by

a) removing any software time limit for hoist response to a command
b) modifying the software to abort the current sonar cycle in response to a retraction signal and automatically resuming operation with a new ping cycle in response to a full extension.
c) provide automatic retraction in response to a transducer flood condition.

5.2 Mechanical

5.2.1 Retraction Mechanism to Ship's Gate Valve

a) this interface shall be compatible with the ship's gate valve flange
b) a watertight seal shall be provided at this interface

5.2.2 Retraction Mechanism to Transducer

a) this interface shall be compatible with the transducer top cover and protective dome
b) a watertight seal shall be provided at this interface

6.0 GENERAL CONSIDERATIONS

It is expected that the MV Arctic will be used for the subsystem installation and sea trials, as the main CDS-40A Sonar has already been fitted. The following considerations assume the use of the ship.
Maximum ship's speeds of 18 knots in open water and 10 knots during ice breaking operation are projected.
It is anticipated that during ice ramming operation the ship's speed in reverse is not greater than approximately 2 knots. Main sonar forward detection capability is not needed when reversing; additionally the probability of rear collision of the transducer with broken ice is high. The transducer will be retracted in this mode.

6.1 Life Expectancy, Reliability and Availability

In view of the experimental nature of the program, the subsystem will be designed with a life expectancy satisfactory for one season's operation by skilled personnel. The subsystem shall be designed to perform reliably, excluding risk of collision, without failure during a test acquisition period, which includes continuous cycling operations daily, for a minimum of 4 weeks. During the test acquisition period the ship is expected to navigate through ice in the breaking or ramming mode.
Additionally, the provision of data gathering capability is limited to the sea trial phase only.

6.2 Repairability

Because of the environmental condition the sybsystem is operated in, the transducer is subject to potential damage by an oncoming block of ice. To cope with this possibility, the subsystem must be designed to allow repair on site with the minimum down time possible. Further, a retraction over the gate valve must be accomplished regardless of the transducer condition after an impact with the ice.
For this purpose, frangible points will be provided within the transducer for the peek and seek modes. The transducer support shall be capable of resisting, without permanent deformation, a blow capable of shearing off the transducer at the frangible point(s).

# APPENDIX D

## CTL REPORT NO. 1069
## "STATEMENT OF WORK - RETRACTION MECHANISM FOR ICE HAZARD DETECTION SONAR"

| REVISIONS | | | |
|---|---|---|---|
| LTR | DESCRIPTION | DATE | APPROVED |
| - | Preliminary, for deliberation | | |

| REV | - | - | - | - | - | - | - | - | - | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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GTECH LTD.
525 BOUNDARY ROAD
CORNWALL, ONTARIO K6H 6N7

| | | |
|---|---|---|
| PREPARED | 14 Oct. '88 | |
| CHECKED | 14 Dec. '88 | |
| APPROVED | 14 DEC. 88 | |

STATEMENT OF WORK -
RETRACTION MECHANISM SUBSYSTEM
FOR ICE HAZARD
DETECTION SONAR

REPORT NO. 1069

SHEET 1 OF 9

C-T557

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## 1.Ø GENERAL

### 1.1 Purpose

The contractor shall provide a subsystem for a retraction mechanism (also addressed within as the subsystem) capable of extending and retracting a sonar transducer from a rest position within a tube into the water environment below a ship.
The application of the subsystem is to protect the transducer, when immersed in water, from damage due to impact with oncoming ice. The subsystem shall respond to external control signals.
The retraction mechanism must be capable of performing in accordance with the specifications set forth within this report.

### 1.2 Intended use of the Retraction Mechanism

The retraction mechanism is intended for use on a ship designed for operation in the arctic. The sea water temperature variation is from -3 C to 25 C, with hydrostatic pressures up to 431 KPa.

### 1.3 Materials and Coatings

Since the retraction mechanism will operate through a ship's hull, the subsystem is divided into two sections; wet and dry. The wet section is completely immersed in sea water. The area where the dry section is located will occasionally contain salt water. Although the water level is kept below the gate valve-retraction mechanism interface, the environment is such that it promotes corrosion.

#### 1.3.1 Dry section

The part of the subsystem which is located inside the ship must be protected from salt water splash. All exposed surfaces must be made with non corrosive materials or protected with anti corrosive finishes.

#### 1.3.2 Wet section

The part of the subsystem which is exposed to the salt water environment shall be made of materials which are of the corrosion resistant type (such as stainless steel type 316). Where corrosive materials are used, all exposed surfaces shall be protected with anti-corrosion and anti-fouling finishes.

### 1.4 Interface and general requirements

The subsystem shall be designed to interface with a sonar transducer and a ship, and perform while observing the following requirements:

1. Operate reliably in a salt water environment.
2. Retain water seal integrity in all navigation conditions.
3. Interface with a ship's tube (valve stool) and a gate valve.
4. Retract the transducer over the gate valve.
5. Extend the transducer below the bottom of the ship.
6. Extend and retract the transducer with sufficient power to overcome forces presented by:
   a) Ice debris accumulated within the gate valve and valve stool
   b) The resistance due to lift and drag encountered at ship's speeds of up to 18 knots
   c) Weight and acceleration demand, to retract within the specified time intervals.
7. Extend and retract the transducer to the specified positions for the various operating modes.

### 1.5 Integration

The retraction subsystem must be designed to integrate with the following other subsystems:

a) The transducer assembly, which is mounted to the underwater section of the retraction mechanism, with all sonar interconnecting cables passing through the retraction mechanism.

b) An alarm processor interfacing with the main sonar and an ice detecting proximity sounder; this processor will provide the retraction subsystem with individual relay contact closures for a system power pilot and position request signals for positions 1 through 5, using a single isolated common.
The retraction subsystem's integral resident controller must provide individual relay contact closure position feedback signals for positions 1 through 5 using a single isolated common.
Interface signal levels shall not exceed 28V DC.

c) Ship's gate valve.

d) Ship's power source.

## 2.0 SPECIFICATION

### 2.1 Location and Interfaces

The retraction mechanism will be located in a ship's sonar compartment, next to the bottom of the hull (Ref. fig. 1).
Access to the underwater environment is made possible via a flanged tube welded to the bottom of the ship. A gate valve is fitted to the tube's flange, to maintain water seal integrity while the sonar is in the non-operating mode.
The retraction mechanism shall be terminated with a flange which is designed to interface with the top cover of the transducer. Provisions shall be made to allow the transducer cables, extending from the cover, to feed through the retraction mechanism without the necessity of removing the connectors. Further, the retraction mechanism-transducer interface shall include a water seal, i.e. "O" ring or gasket.

### 2.2 Load capacity and conditions

Although the static load is reasonably small (less than 45 Kg) the conditions are such that the actual apparent load can be greater than 454 Kg.
The ship's speed, retraction mechanism weight and frictions, and retraction time shall be considered in determining the load capacity.

### 2.3 Travel

#### 2.3.1 Distance of travel

The retraction mechanism must be capable of travelling to accommodate the following:

| | | |
|---|---|---|
| Main transducer | 330 mm | |
| Proximity transducer | 178 mm | |
| Total transducers | | 508.0 mm |
| Tube (valve stool) | 228.6 mm | |
| Gate valve | 292.1 mm | |
| Gasket (2) | 12.7 mm | |
| Total distance between bottom of the hull and top of gate valve blade | | 431.8 mm |
| Minimum distance above gate valve | | 19.0 mm |
| Total travel distance | | 958.8 mm |

### 2.3.2 Transducer position within travel

When in the operational mode, the sonar system will detect ice while the transducer is in various positions within the retraction mechanism's travel.

The modes of operation and transducer positions are as follows:

| Position | Operating Mode | Transducer bottom W.R.T. ship's hull distance in mm |
|---|---|---|
| 1 | Rest | 431.8 |
| 2 | Clear | 25.4 |
| 3 | Hide | 384.8 |
| 4 | Peek | -177.8 |
| 5 | Seek | -508.0 |

### 2.3.3 Speed of travel

The extension and retraction speeds of the retraction mechanism are dependent on the direction of the travel, and whether it is a simple request to lower/retract or a retraction alarm.

When the ship is in the ice breaking mode, the retraction mechanism is required to occasionally push the ice debris out from below the transducer (Rest to Clear mode). The travel speed for this task should be set to minimize the danger of damaging the transducer in the ice clearing mode. (200 mm/sec is used below as a nominal speed). When extending from Hide-to-Peek and Peek-to-Seek modes the speeds must be set to minimize the blind periods.

Once the transducer is out of the tube and below the ship (Peek or Seek mode), and an oncoming ice block alarm is given, the time available for retraction can be very short (depending on the ship's speed), therefore imposing very short reaction time and fast retraction speeds.

The positions with their respective speed of travel for a reaction time not greater than 50 milliseconds are given below:

| | From Position to Position | | Total travel mm | Avg Speed mm/sec | Total time seconds |
|---|---|---|---|---|---|
| | 1 (431.8) | 2 (25.4) | 406.4 | 200 | 2.032 |
| | 2 (25.4) | 3 (384.8) | 359.4 | 200 | 1.797 |
| * | 3 (384.8) | 4 (-177.8) | 562.6 | 667 | .843 |
| * | 4 (-177.8) | 3 (384.8) | 562.6 | 667 | .843 |
| * | 4 (-177.8) | 5 (-508.0) | 330.2 | 667 | .495 |
| * | 5 (-508.0) | 3 (384.8) | 892.8 | 667 | 1.339 |

* Critical extension and retraction speeds

While the ship is navigating through ice in the breaking or ramming mode, the retraction mechanism will be subjected to continuous cycling between positions 2-3-4-2-..... and 2-3-4-5-2-.....

During the cycling operations, the subsystem shall be capable of maintaining the speed and travel accurately and reliably within 6mm.

### 2.4 Available Power

The available power which can be used as a source of supply for the retraction mechanism is expected to be 115 VAC.
(The availability of other sources of supply could be investigated.)

### 2.5 Available Area

The available space for the installation of the retraction mechanism is as shown in figure 1.

#### 2.5.1 Access to the available area

Transportation of the subsystem to the available area may be restricted to existing man holes within a crane tower. The crane tower is located directly above an area approximately 1 m and two steel plate walls away from the sonar compartment. The distance between the two walls is approximately .735 m (Ref. Fig. 1 detail 2C).

#### 2.5.2 Transport for Installation

Access to the compartment may be via man holes having dimensions ranging from .457 m diameter to .610 x .457 m elongated circles. Because of the compartment shapes and the man hole locations, the retraction mechanism may have to be transported in short and narrow sub-assemblies.

### 2.6 Repairability

Because of the environmental condition the subsystem is operated in, the transducer is subject to potential damage by an oncoming block of ice. To cope with this possibility, the subsystem must be designed to allow repair on site with the minimum down time possible. Further, a retraction over the gate valve must be accomplished regardless of the transducer condition after an impact with the ice.
For this purpose, frangible points can be provided within the transducer (for the peek and seek modes). The transducer support shall be capable of resisting, without bending, a blow capable of shearing off the transducer at the frangible point(s).

### 2.7 Reliability

The subsystem shall be designed to perform reliably without failure during a test acquisition period, which includes continuous cycling operations daily, for a minimum of 4 weeks. During the test acquisition period the ship is expected to navigate through ice in the breaking or ramming mode.
Further, the subsystem shall operate reliably, providing it is adequately maintained, for a minimum period of one year.

## 3.0 PROJECT PLAN

### 3.1 System design

Prior to detail design the contractor shall prepare a conceptual design approach. The design approach, complete with all necessary visual aids, shall be presented in a design review with C-Tech Engineering personnel at C-Tech's facilities.

### 3.2 Detailed Design

The detailed design will be performed in this stage of work.
The contractor will prepare Engineering drawings suitable for the

manufacturing of the subsystem.
Design review will be held with C-Tech Engineering personnel at C-Tech's facilities. This design review will present a detailed design description of the subsystem.

### 3.3 System Test

#### 3.3.1 Test Methods

Detailed test methods shall be provided by the contractor to C-Tech Ltd for the following:

a) Position repeatability
b) Speed - extending and retracting (with simulated drag applied)
c) Position feedback accuracy
d) Load capacity
e) Cycling effect for a 24 hour duration
f) Operation at cold temperature (-3 deg C)
g) Water seal integrity.

#### 3.3.2 Testing

The contractor shall test the subsystem in accordance with the detailed test methods and submit results to C-Tech Ltd. for approval.
C-Tech Ltd. reserves the right, at its discretion, to have a representative present to observe the testing.

### 3.4 System Integration

Support shall be provided to C-Tech Ltd. for the integration of the retraction mechanism with the Ice Hazard Detection Sonar system.

### 3.5 Training

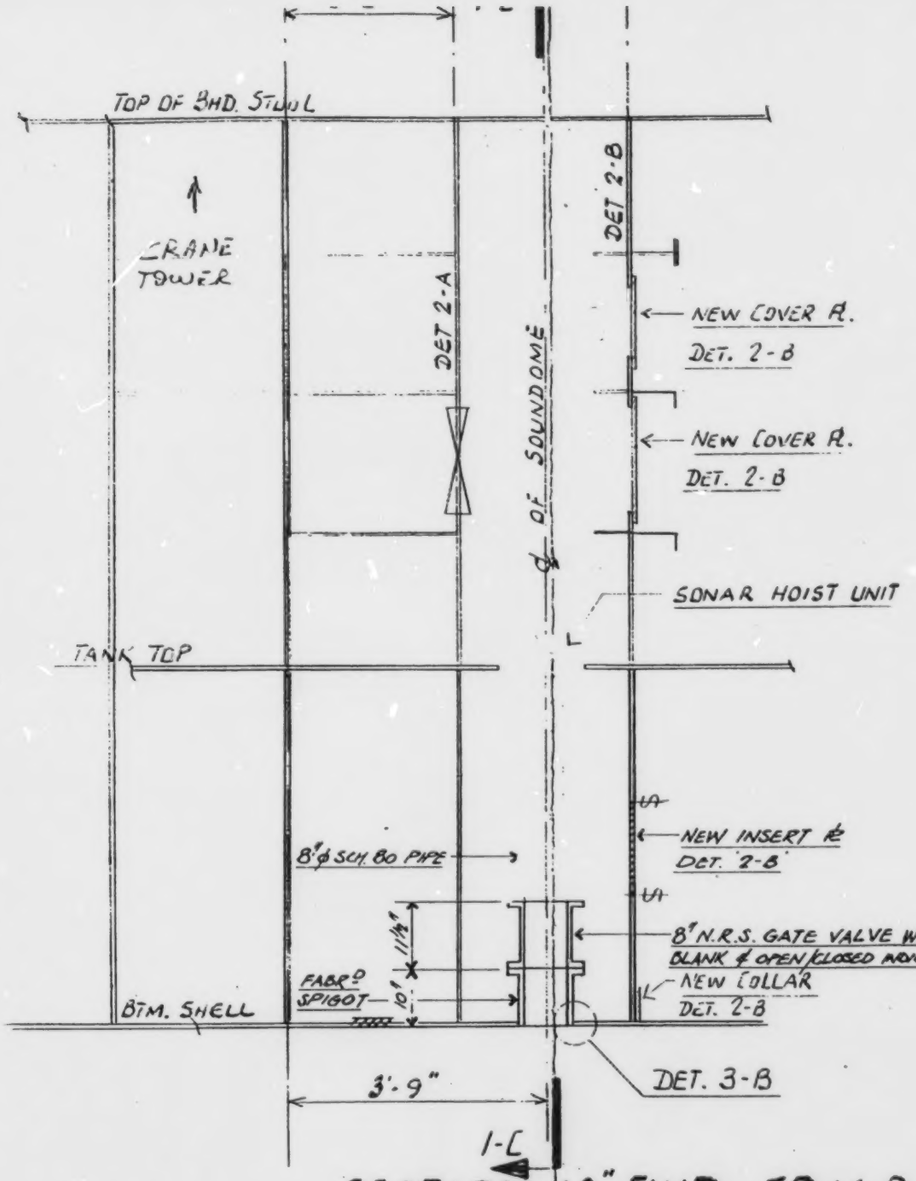
C-Tech personnel will be trained in the design concept, application and maintenance of the subsystem.

### 3.6 Design Disclosure

The complete design description in the form of Engineering drawings shall be provided to C-Tech Ltd.
These drawings shall bear the seal of a professional Engineer to certify the suitability for the application.

## 4.0 SCHEDULE

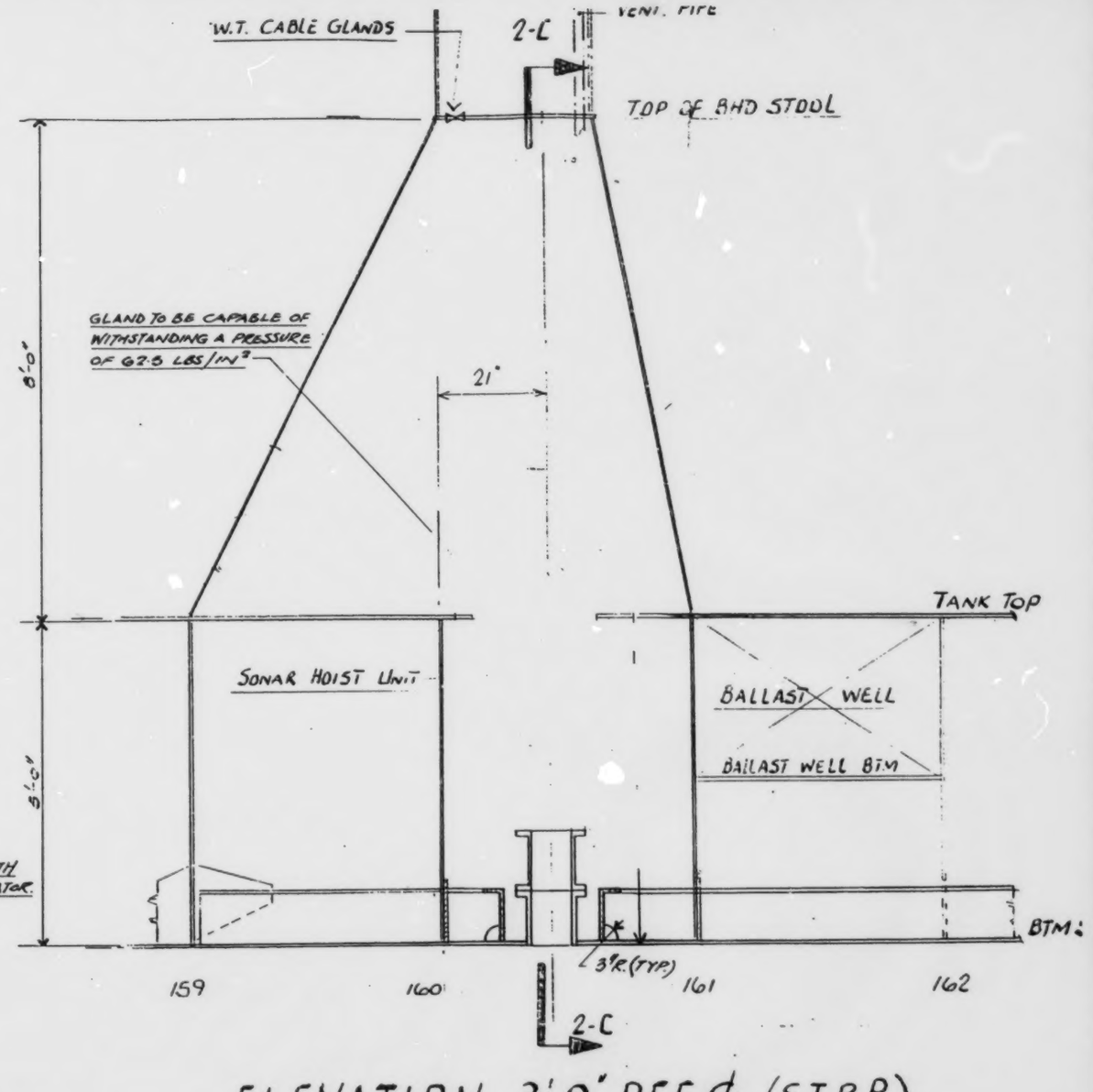
The retraction mechanism subsystem design, fabrication and tests shall be completed and the finished mechanism delivered by April 15, 1989.




## SECTION 12" FWD FR160

LOOKING FORWARD

## DETAIL 2-C




## ELEVATION 3'-9" OFF ℄ (STB$^D$)

LOOKING INBOARD

## DETAIL 1-C

FIGURE 1: Sonar Compartment
Sheet 1 of 2

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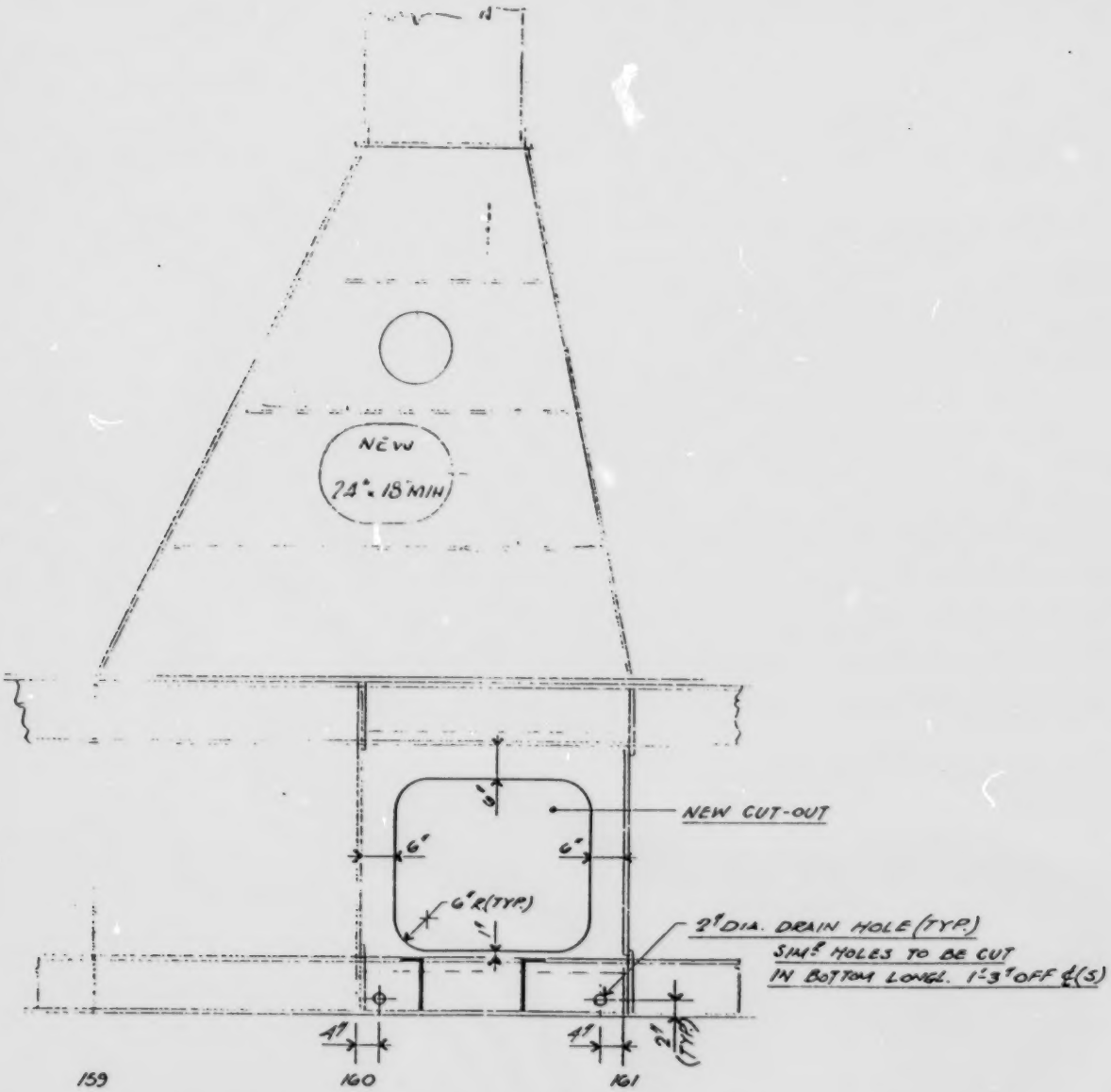
|---|---|
| REV. - | SHEET 8 |




ELEVATION 2'-6" OFF ℄ (STB$^D$)

DETAIL 2-A

FIGURE 1: Sonar Compartment

Sheet 2 of 2

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|---|---|
| REV. - | SHEET 9 |

# APPENDIX E

## CTL SKETCH NO. A-1098
## "RETRACTION MECHANISM CONTROLLER FOR ICE HAZARD DETECTION SONAR"

# RETRACTION MECHANISM CONTROLLER

# FOR ICE HAZARD DETECTION SONAR

SKETCH NO. A-1098

PREPARED: 17-11-89 RVdB
APPROVED: 17-11-89 RVdB

| ISSUE | DATE | APPROVED |
|---|---|---|
| 1 | 17-11-89 | RVdB |

This sketch consists of:
a) sheets 1 thru 8
b) attachments A1 thru A4
B1 thru B2
C1 thru C9
D1 thru D2
E1 thru E8
F1 thru F2

## RETRACTION MECHANISM CONTROLLER FOR ICE HAZARD DETECTION SONAR

1.0 Purpose: The controller shall, in response to external control signals, direct and monitor a retraction mechanism to extend and retract a sonar transducer from a rest position, through several intermediate positions, into the water environment below a ship. The application of the mechanism is to protect the transducer, when immersed in water, from damage due to impact with oncoming ice.

2.0 Interface and General Requirements:

The controller shall be designed to interface with a proximity alarm processor and shall control retraction mechanism position via solenoid type hydraulic control valves while monitoring the mechanism stroke via a linear variable differential transformer. All power and interface requirements for the solenoid control valves and for the LVDT are to be provided by the controller.

2.1 Positioning Requirements

When in the operational mode, the sonar system will detect ice while the transducer is in various positions within the retraction mechanism's travel. The modes of operation and respective transducer positions are as follows:

| Position | Operating Mode | Transducer bottom W.R.T. ship's hull distance in inches |
|---|---|---|
| 1 | Rest | 18.00 |
| 2 | Clear | 1.00 |
| 3 | Hide | 15.15 |
| 4 | Peek | -6.00 |
| 5 | Seek | -20.00 |

Note that positions 1 and 5 are end-of-stroke positions.

The activation modes are given below:

| from position | to position |
|---|---|
| 1 | 2 |
| 2 | 3 |
| 3 | 4 |
| 4 | 3 |
| 4 | 5 |
| 5 | 3 |

While navigating through ice, the retraction system may be subject to periods of continuous cycling between positions 2-3-4-2 and 2-3-4-5-2. The extension/retraction speed is approximately 60 inches/second.
During cycling operations the controller must control the hydraulics to accurately and reliably attain requested positions within 0.25 inch.

## 2.2 Proximity Alarm Processor Interfaces

### 2.2.1 Control Interface:

The Alarm Processor provides reed relay contact closures for the following control signals using a single isolated common via the specified connector; signals are maintained as long as the positions are required:

| function | connector pin |
|---|---|
| power pilot (system active) | 10 |
| rest request | 15 |
| clear request | 16 |
| hide request | 11 |
| peek request | 12 |
| seek request | 13 |
| request common | 14 |

Rest mode will be the power off default condition. Interface signal levels shall not exceed 28VDC.

The Hoist Controller provides normally open transistor optocoupler outputs capable of driving one TTL logic unit load for the following status feedback signals using a single isolated common; signals are active (closed) when the desired position is attained:

| function | connector pin |
|---|---|
| system ready (initialization complete) | 9 |
| rest status | 1 |
| clear status | 2 |

| | |
|---|---|
| hide status | 3 |
| peek status | 4 |
| seek status | 5 |
| status common | 6 |

Cable shield is on pin 7.

2.2.2 LVDT Interface

The controller receives hoist position feedback via a Trans-Tek model 0224-0000 linear variable differential transformer. The ± 20 inch linear LVDT stroke range will be centered on the hoist stroke range.
The controller must provide compatible interfacing, such as the Trans-Tek model 1000-0011, internally.

2.2.3 Monitor Interface

The hoist controller also provides a ± 5VDC analog signal representing hoist position (LVDT interface output) to an isolated proximity alarm processor input port; minimum load resistance will be 100K ohm. Pinning for the specified connector is as follows:

| function | connector pin |
|---|---|
| LVDT high | 1 |
| LVDT low | 2 |
| shield | 3 |

2.2.4 Hydraulic Solenoid Control Valves.

Solenoid activated valves will be used for the hydraulics. The impact of delay time variations in these valves on the control requirements must be considered and power, switch, and software options should be examined to ensure that acceptable positioning accuracy is maintained.
A.C. valves will suffer an 8.3 ms timing resolution if switched via a zero crossing SSR; a non zero crossing switch will apply random AC line phase. Software compensation could be applied if AC line phase is monitored.
If DC operated solenoids are selected, power must be supplied by the controller.
The hydraulic system will, however, use 115 VAC solenoids unless otherwise requested.

2.2.5 Prime Mover Power

A hydraulics prime mover power pilot signal (115VAC, 5A) must be provided by the controller.

Wake-Up
Upon receipt of a power pilot (system active) signal from the Proximity Alarm Processor, the controller will activate the prime mover power pilot. During a suitable hydraulics warm-up period, perhaps 2 minutes, all other requests will be ignored.

Shut-Down
When the system power pilot signal is interrupted, the controller will maintain prime mover pilot power until the retraction mechanism has resumed the default rest state.

2.2.6 Gate Valve Interlock

The controller will monitor the status of the gate valve interlock, and unless this switch contact is closed, should under no circumstances attempt to lower the retraction mechanism.

2.2.7 Local Manual Operation

The controller will provide internal switches, including a change over switch, to allow local operation of the retraction mechanism.

2.2.8 Power

The controller shall derive all necessary operating power from ship's 115VAC 60Hz mains via the specified connector.

2.2.9 Physical

The controller dimensions must not exceed 16" H X 16" W X 8" D due to installation space restrictions. Connectoring is to be on the bottom surface of a Hammond no. 1418G8 enclosure oriented as shown in the supplied sketch. Due to the hostile environment, no penetration should exist on any other surface. The controller housing should house the controller itself, the interface for the position sensing LVDT, necessary power supplies to operate off 115 VAC, relays to provide switched pilot power to the hydraulics control valves, and to provide switched 115 VAC pilot power for the hydraulics prime mover power contactor.

2.2.10 Additional Operational Constraints

2.2.10.1 Operator Intervention The controller shall be capable of operating in all modes, i.e. start-up, self-calibration, response to proximity transceiver alarm processor requests, and shutdown request, without operator intervention. Access to the controller will not be possible in normal operation.

2.2.10.2 Environmental The ambient operating temperature range for the controller will be 0°C - 45°C.

2.2.10.3 Adaptive Control Rest and seek positions are at the limits of cylinder stroke and do not present an overshoot problem. When either of these positions is requested the cushioned cylinder can be moved to its limit.
In order to stop in the hide, clear, or peek positions, the controller must center the directional control valve when the LVDT indicates a position some predetermined distance ahead of the required position, thus allowing for overshoot. The overshoot, estimated from cylinder velocity and valve response time, may vary with operating conditions, e.g. oil temperature, and thus it would be desirable to use predictive adaptive control based on overshoot history. Multiple adaptive repositionings in response to a single command cannot be used, since response times to alarm conditions are critical to the system.

2.2.10.4 Initial Self-Calibration Immediately after the system wake-up hydraulics warm-up period, the controller will continue to ignore position request signals and enter a self-directed adaptive calibration mode, where it will cycle as required thru the in-tube positions only (i.e. rest-hide-clear). Upon completion of the calibration cycle, the controller will position the retraction mechanism in the rest state and activate a system ready pilot signal.
The controller will then begin responding as required to the active request line.

2.2.10.5 Operating Recalibration When in the normal operational phase, i.e. proximity transceiver alarm processor request driven after the initial calibration phase, a recalibration attempt in response to a positioning error should be made only on a clear request.

Calibration attempts on the active detection portions of the operational cycle, i.e. hide-peek-seek, present an uncompensated response time problem for the proximity sounder. However, adaptive error compensation may be included on any positioning attempt.

2.2.10.6 Reliability The subsystem shall be designed to perform reliably without failure during a test acquisition period, which includes continuous cycling operations daily, for a minimum of 4 weeks. Further, the subsystem shall operate reliably, providing it is adequately maintained, for a minimum period of one year. All controller software or firmware shall be ROM based only.

## 3.0 PROJECT PLAN

### 3.1 System Design

Prior to detail design the contractor shall prepare a conceptual design approach. The design approach, complete with all necessary visual aids, shall be presented in a design review with C-Tech Engineering personnel at C-Tech's Facilities.

### 3.2 Detailed Design

The detailed design will be performed in this stage of work. The contractor will prepare Engineering drawings suitable for the manufacturing of the subsystem.
Design review will be held with C-Tech Engineering personnel at C-Tech's facilities. This design review will present a detailed design description of the subsystem.

### 3.3 System Integration

Support shall be provided to C-Tech Ltd. for the integration of the retraction mechanism controller with the Ice Hazard Detection Sonar System.

### 3.4 Training

C-Tech personnel will be trained in the design concept, application and maintenance of the subsystem.

### 3.5 Design Disclosure

The complete design description in the form of Engineering drawings shall be provided to C-Tech Ltd.

## 4.0 Supplementary System Information

The following sketches, available separately, also form a part of this specification:

1. "Ice Hazard Sonar System - Operation of Hydraulic Circuit (Abridged)", CTL sketch # A-1084

2. Ice Hazard Sonar - Hydraulic Circuit Diagram, CTL sketch # CD2157-3, and Parts List, CTL sketch # CD2157-4.

3. "Hoist Controller Envelope and Interconnections", CTL sketch # C-1075

The following attachments provide data on selected system components:

A. Data Sheet, Trans-Tek LVDT

B. Data Sheet, Trans-Tek LVDT Oscillator-Demodulator

C. Data Sheet, Hydraulic Valve Solenoids

D. Data Sheet, Power Contactor

E. Data Sheets, Amp Connectors

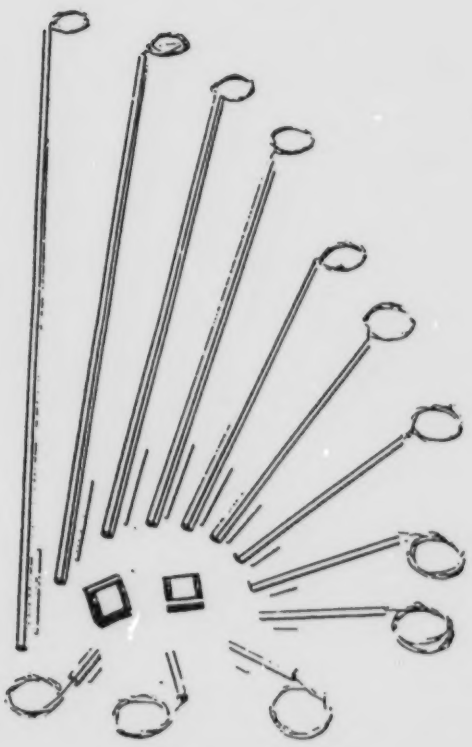
F. Data Sheet, Hammond cabinet.

0224-0000

TRANS-TEK INCORPORATED

# AC LVDTS SERIES 210-220 OSCILLATOR/DEMODULATOR

## MODELS 1000-0011 1000-0012



*LINEAR DISPLACEMENT MEASUREMENT SYSTEM.*

- ☐ GUARANTEED SYSTEM PERFORMANCE
- ☐ STANDARDIZED ±5 VDC OUTPUT
- ☐ .25% MAXIMUM NON-LINEARITY
- ☐ INFINITE RESOLUTION
- ☐ MEASUREMENT RANGES FROM ±.25 TO ±30 INCHES
- ☐ LOW TEMPERATURE COEFFICIENT
- ☐ AUTOMATIC PHASE SYNCHRONIZATION WITH NO ADJUSTMENT

The SERIES 210-220 AC LVDTs offer precision linear measurements for applications with full strokes of from 0.5 to 60 inches. The transducers have been designed to provide a temperature coefficient of sensitivity below 0.01%/°F and non-linearities of less than 0.25% F.S. The full scale output and packaging are but two of the many parameters which have been standardized to provide the designer the ability to change measurement ranges with the confidence that total system performance will not be affected. The SERIES 210-220 LVDTs utilize variable pitch secondary windings. This technique not only reduces the package length to stroke ratio, but also eliminates the flat spots or steps which occur in the output of other LVDTs which use step winding or are wound with a series of discrete segments. Computer controlled winding machines are used to assure a uniformly high product quality.

To speed the development of prototype systems and for users who prefer not to assemble AC support electronics, the Models 1000-0011 and 1000-0012 Oscillator/Demodulator modules allow the LVDTs to be operated as part of a DC in, DC out system. The buffered ±5.0 VDC output can be fed directly into most microprocessor based control loops or computer input cards. The design of the modules is so well tailored to the SERIES 210-220 that there is no difference in guaranteed performance between a complete DC system and the transducers used as AC LVDTs. Standard features include internal voltage regulation, trimming circuits for zero and span, along with a unique demodulator which eliminates errors associated with phase shift due to core position.

BULLETIN SO12-0069 FHH

SKETCH NO. A-1098
SHEET A1

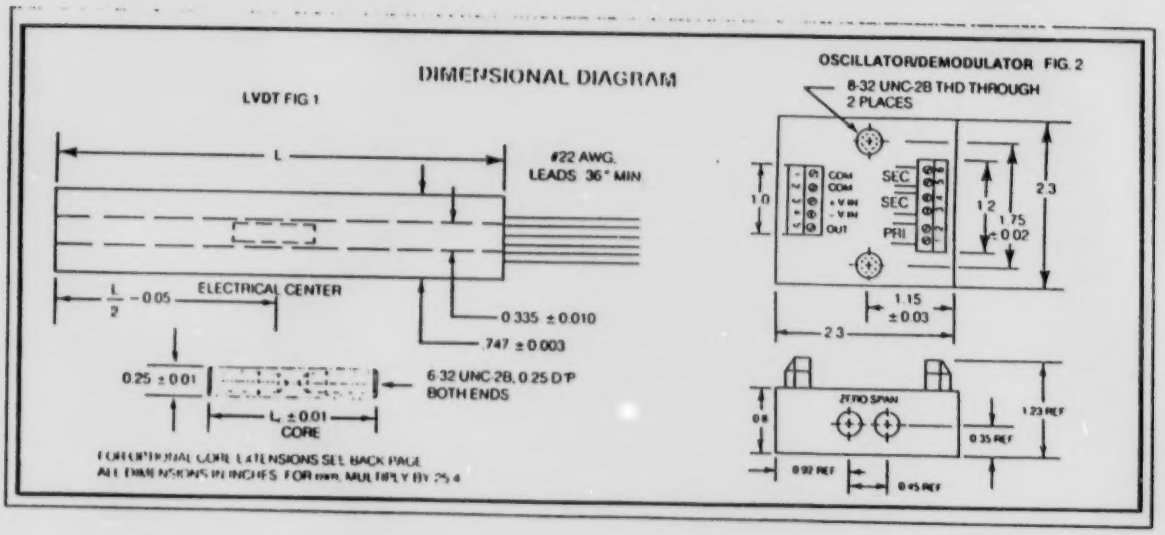
AC/AC LVDTS WITH OSCILLATOR/DEMODULATOR

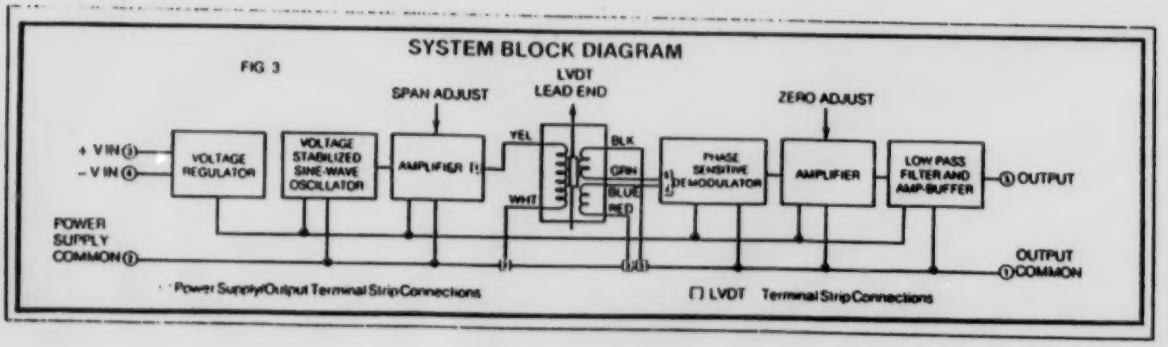
# DESCRIPTION

The Trans-Tek SERIES 210-220 AC LVDTs, and companion Oscillator/Demodulators have been designed together to provide optimized temperature coefficient and guaranteed system non-linearity of less than 0.25%. Working from an unregulated DC input, the Model 1000-0011 or 1000-0012 Oscillator provides a sinusoidal voltage. The gain of the oscillator amplifer is adjustable via the span control but is very stable for any control setting. The core resides in the transducer's body and is connected to the measured part by a separate extension rod (optional). This ferro-magnetic core induces separate AC voltage into each of the LVDT's two secondary coils; the amplitude of each resulting voltage is a function of the core's position relative to the transducer's electrical center. In the Demodulator section of the 1000-0011 and 1000-0012, the two secondary voltages are differenced and rectified, eliminating quadrature null voltage and converting the output to a DC voltage. Additional circuitry is incorporated to eliminate errors induced by phase shift due to core position and to provide zero adjustment. The filter/buffer stage provides the right blend of frequency response versus output ripple while delivering a low output impedance.

# SYSTEM CONFIGURATION

For specified performance use the Model 1000-0012 Oscillator/Demodulator with LVDT MODELS 0215-0000 thru 0222-0000. For MODELS 0223-0000 thru 0226-0000, the MODEL 1000-0011 should be used. When wired as shown in the SYSTEM BLOCK DIAGRAM below the output goes more positive as the core moves toward the lead end of the LVDT. To invert the system's output voltage, reverse the green and blue connections on the oscillator/demodulator.




SKETCH NO. A-1098
SHEET A2

## SYSTEM SPECIFICATIONS

(Combined Performance of LVDT and Oscillator/Demodulator)

| |
|---|
| LINEARITY: ≤0.25% FS (Best Fit Straight Line) |
| INPUT: ± 14.5 to ± 28.0 VDC, ± 100 mA max<br>Internal regulation and input reversal protection provided. |
| OUTPUT: Adjustable to ± 5.0 VDC at end of linear stroke, via SPAN adjustment |
| FREQUENCY RESPONSE (– 3 db): Systems with 1000-0011, 500 Hz min.<br>Systems with 1000-0012, 1000 Hz min. |
| OUTPUT RIPPLE: <0.03 VRMS Max. |
| TEMPERATURE COEFFICIENT: < ± 0.0035% FS/°F Zero, < ± .02% reading/°F Span |
| TEMPERATURE RANGE: LVDT: – 67°F to + 257°F Operating, – 67°F to + 275°F Storage<br>OSC/DEM: + 32°F to + 158°F Operating, – 67°F to + 257°F Storage |

## TRANSDUCER SPECIFICATIONS[1]

| |
|---|
| LINEARITY: ≤0.25% FS (Best Fit Straight Line) |
| REFERENCE FREQUENCY: Models 0215-0000 thru 0222-0000, 7.0 KHz<br>Models 0223-0000 thru 0226-0000, 3.0 KHz |
| SENSITIVITY: 0.50 V/V ± 10% at FULL SCALE |
| INPUT VOLTAGE: 20 VRMS, Max. |
| NULL VOLTAGE: ≤1.0% Excitation Voltage |
| TEMPERATURE COEFFICIENT: < ± 0.001% FS/°F Zero, < ± 0.01% reading/°F Span |
| OUTER HOUSING: 300 series stainless steel |
| BORE LINER: 300 series stainless steel |
| CORE: Chrome plated iron/nickel alloy |

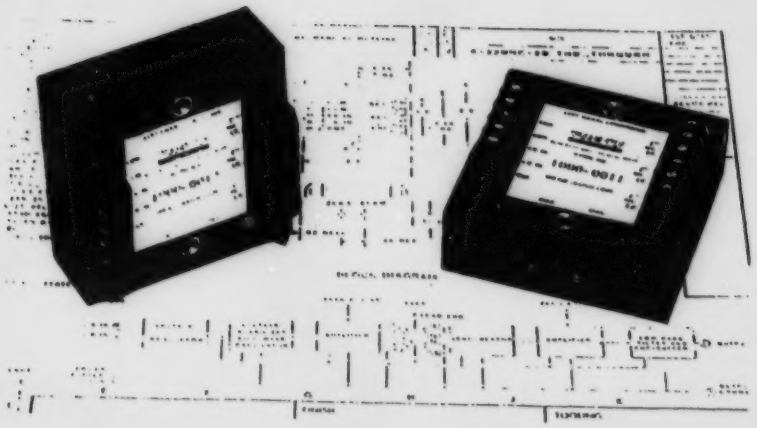
| MODEL | LINEAR RANGE | MAX USABLE RANGE[2] | BODY LENGTH (L) Fig. 1 | CORE PART NUMBER[4] | CORE LENGTH ($L_c$) Fig. 1 | CORE MASS | INPUT IMPEDANCE | DC INPUT RESISTANCE | OUTPUT IMPEDANCE | PHASE[3] ANGLE |
|---|---|---|---|---|---|---|---|---|---|---|
| 0215-0000 | ± 0.25 | ± 0.65 | 2.50 | C005-0108 | 1.0 | 5.1 | 205 | 22 | 265 | 13 |
| 0216-0000 | ± 0.50 | ± 0.95 | 3.25 | C005-0108 | 1.0 | 5.1 | 235 | 31 | 310 | 17 |
| 0217-0000 | ± 1.0 | ± 1.45 | 4.50 | C005-0113 | 1.25 | 6.6 | 195 | 36 | 205 | 19 |
| 0218-0000 | ± 2.0 | ± 2.7 | 7.50 | C005-0107 | 1.5 | 8.1 | 200 | 46 | 255 | 22 |
| 0219-0000 | ± 3.0 | ± 3.8 | 10.0 | C005-0106 | 1.9 | 10.9 | 225 | 57 | 285 | 25 |
| 0220-0000 | ± 5.0 | ± 5.95 | 15.0 | C005-0105 | 2.5 | 14.7 | 360 | 89 | 460 | 31 |
| 0221-0000 | ± 7.5 | ± 8.45 | 21.5 | C005-0104 | 4.0 | 24.5 | 235 | 55 | 235 | 30 |
| 0222-0000 | ± 10.0 | ± 11.0 | 28.0 | C005-0103 | 5.5 | 34.4 | 330 | 72 | 285 | 31 |
| 0223-0000 | ± 15.0 | ± 16.4 | 40.0 | C005-0100 | 7.0 | 44.4 | 450 | 57 | 395 | 25 |
| → 0224-0000 | ± 20.0 | ± 21.3 | 50.0 | C005-0100 | 7.0 | 44.4 | 660 | 100 | 580 | 30 |
| 0225-0000 | ± 25.0 | ± 26.2 | 60.0 | C005-0100 | 7.0 | 44.4 | 210 | 41 | 355 | 28 |
| 0226-0000 | ± 30.0 | ± 31.3 | 70.0 | C005-0100 | 7.0 | 44.4 | 200 | 45 | 410 | 30 |
| UNITS | INCHES | INCHES | INCHES | | INCHES | GRAMS | OHMS | OHMS | OHMS | DEG. |

NOTES: 1. SPECIFICATIONS AT REFERENCE FREQUENCY.
2. Min. stroke before voltage reversal occurs.
3. Output voltage lags excitation voltage.
4. Each LVDT is shipped with one core. Core extension rods or extra cores must be ordered separately.

SKETCH NO A 1098 SHEET A3

TRANS-TEK INCORPORATED

# OSCILLATOR DEMODULATOR MODULES FOR AC LVDTS
## MODELS 1000-0011 1000-0012



- ☐ INTERNAL VOLTAGE REGULATION
- ☐ ZERO AND SPAN ADJUSTMENTS
- ☐ AUTOMATIC PHASE SYNCHRONIZATION
- ☐ OPERATES IN 4, 5 OR 6 WIRE SYSTEMS
- ☐ MULTI-POLE ACTIVE OUTPUT FILTER
- ☐ COMPACT, RUGGED PACKAGE

The 1000-0011 and 1000-0012 provide complete electrical support for AC LVDTs. Working from an unregulated DC input the modules generate a stable sinusoidal voltage to excite the transducer. The differential AC voltages from the LVDT's secondaries are converted to DC by the module's synchronous demodulator. The demodulator has automatic phase synchronization which simplifies calibration by eliminating the need to make adjustments to compensate for the transducer's phase angle. An active, multi-pole filter in the final stage reduces output ripple and maximizes frequency response. Other features include zero and span controls, full encapsulation, threaded inserts for mounting and self-locking terminal strips.

### ELECTRICAL SPECIFICATIONS

| | | |
|---|---|---|
| INPUT POWER | VOLTAGE | ± 14.5 TO ± 28 VDC, Input polarity protected |
| | CURRENT | ± 100mA max plus LVDT current |
| OSCILLATOR OUTPUT TO LVDT | VOLTAGE | 4.25 to 5.75 VRMS adjustable via 15 turn span control |
| | FREQUENCY | 1000-0011: 3.0 KHz, ± 10%, sine wave<br>1000-0012: 7.0 KHz, ± 10%, sine wave |
| | CURRENT | Will drive LVDTs with primary impedance of 100 ohms or greater. Short circuit and thermally protected |
| SIGNAL OUTPUT | VOLTAGE | DC output is 2 times the RMS output of the LVDT. Output voltage is limited to ± 12 VDC |
| | CURRENT | ± 3mA without distortion |
| | IMPEDANCE | Less than 5 ohms |
| | RIPPLE | 0.015 VRMS max |
| | FREQ. RESPONSE (-3db) | 1000-0011: 500 Hz min., 1000-0012: 1000 Hz min. |
| ACCURACY | NON-LINEARITY | ± 0.05% max over ± 10 VDC output |
| | TEMP. COEF. | < ± 0.00025V/°F Zero, < ± 0.01% output/°F Span |
| TEMPERATURE RANGE | OPERATING[1] | + 32°F to + 158°F (0°C to + 70°C) |
| | STORAGE | − 67°F to + 257°F (− 55°C to + 125°C) |
| ZERO ADJUSTMENT | | ± 0.40 min. VDC via 15 turn zero control |
| TERMINAL CONNECTIONS | | Friction terminals with self-locking screws, accepts #22 – #16 AWG wire |

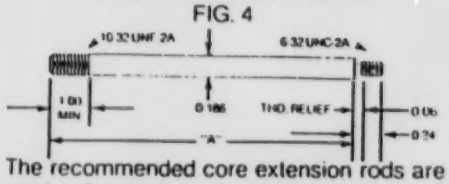
BULLETIN SO12-0070 FHH [1]Extended temperature range available — Consult Factory

SKETCH NO A-1098 SHEET B1

OSCILLATOR/DEMODULATOR

## CORE EXTENSIONS

FIG. 4




The recommended core extension rods are made of non-magnetic stainless steel and are sized to allow the transducers to operate over their full range. Extension rods from models with longer strokes may be used to facilitate installation. The use of extension rods shorter than recommended may reduce the LVDT's usable measurement range.

ALL DIMENSIONS IN INCHES

| LVDT MODEL NO. | RECOMMENDED CORE EXTENSION ROD | DIMENSION A FIG 4 |
|---|---|---|
| 0215-0000 | C006-0174 | 3.0 |
| 0216-0000 | C006-0175 | 3.6 |
| 0217-0000 | C006-0176 | 4.7 |
| 0218-0000 | C006-0177 | 7.2 |
| 0219-0000 | C006-0178 | 9.3 |
| 0220-0000 | C006-0179 | 13.7 |
| 0221-0000 | C006-0180 | 19.0 |
| 0222-0000 | C006-0181 | 24.2 |
| 0223-0000 | C006-0182 | 35.0 |
| 0224-0000 | C006-0183 | 45.5 |
| 0225-0000 | C006-0184 | 56.0 |
| 0226-0000 | C006-0185 | 66.5 |

## TRANS-TEK'S PRODUCTS ARE MARKETED NATIONALLY AND INTERNATIONALLY THROUGH OUR SALES REPRESENTATIVE SYSTEM.

### MODIFICATIONS

Transducers and electronics for special applications are available. Consult Trans-Tek, Inc. on your particular requirements.

### ORDER PLACEMENT

**United States:** orders should be made out to TRANS-TEK, Inc., sent in care of your local TRANS-TEK representative, or directly to TRANS-TEK, P.O. Box 338, Ellington, Ct. 06029. **International:** contact your local TRANS-TEK representative.

### WARRANTY

All Trans-Tek transducers are warranted against defective materials and workmanship for one year.

### NOTES

All specifications and prices subject to change without notice. Contact Trans-Tek for quantity discount prices available on all models and on combined orders. (For areas beyond the United States . . . contact the international representative.)

TELEX 9-9207 (TRANS TEK ELLG)

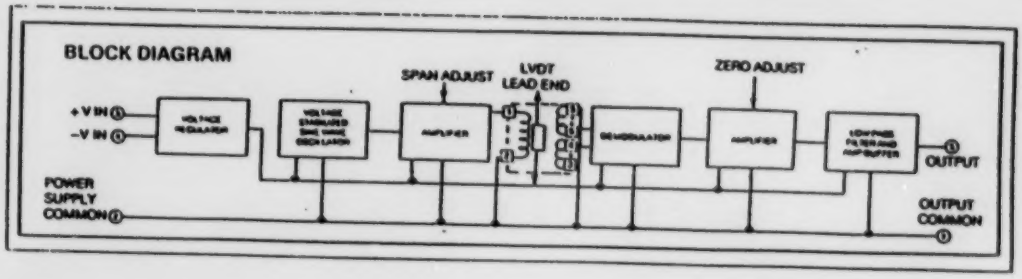
Printed in U.S.A.

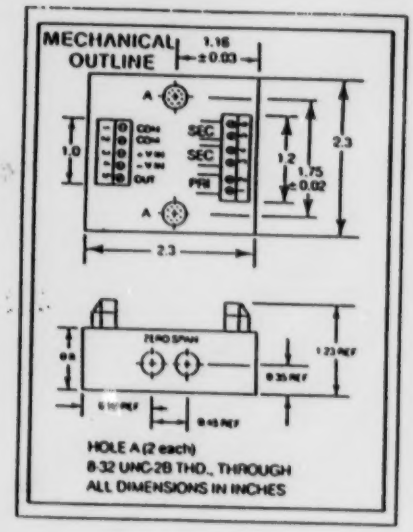
TRANS-TEK INCORPORATED

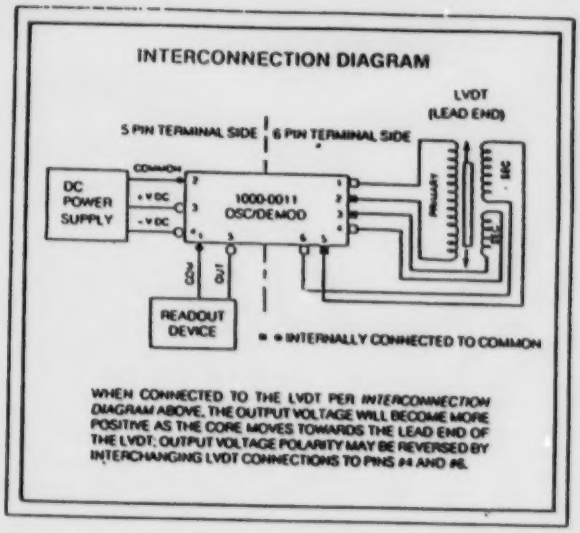
Route 83, P.O. Box 338, Ellington, Connecticut 06029 (203) 872-8351

SKETCH NO. A-1098 SHEET 44

OSCILLATOR/DEMODULATORS





INTERCONNECTION DIAGRAM
LVDT (LEAD END)
5 PIN TERMINAL SIDE
6 PIN TERMINAL SIDE
DC POWER SUPPLY
COMMON
+V DC
-V DC
1000-0011 OSC/DEMOD
READOUT DEVICE
* = INTERNALLY CONNECTED TO COMMON
WHEN CONNECTED TO THE LVDT PER INTERCONNECTION DIAGRAM ABOVE, THE OUTPUT VOLTAGE WILL BECOME MORE POSITIVE AS THE CORE MOVES TOWARDS THE LEAD END OF THE LVDT. OUTPUT VOLTAGE POLARITY MAY BE REVERSED BY INTERCHANGING LVDT CONNECTIONS TO PINS #4 AND #6.

## ORDER PLACEMENT

Orders should be made out to TRANS-TEK, INC., sent in care of your local TRANS-TEK representative, or directly to TRANS-TEK, INC. Box 338, Route 83, Ellington, Connecticut 06029.

## NOTES

Specifications are subject to change without notice. Contact TRANS-TEK for prices and discounts available on all models.

## WARRANTY

All Trans-Tek transducers are warranted against defective materials and workmanship for one year.

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Printed in U.S.A.

TRANS-TEK INCORPORATED

P.O. Box 338 • Route 83 Ellington, Connecticut 06029 Tel. (203) 872-8351

SKETCH NO. A-1098 SHEET B2

# DIRECTIONAL CONTROLS

## MODEL SERIES DG4V - 3 40 DESIGN

## FOUR-WAY DIRECTIONAL VALVES

NOTE: FOR GRAPHICAL SYMBOLS SEE PAGE 5.

### GENERAL DATA

DG4V-3 models are direct solenoid operated four-way directional control valves. Their primary function, in a hydraulic circuit, is to determine the direction of fluid flow to a work cylinder, or control the direction of rotation of a fluid motor. Port connections are made by mounting the valve on a subplate or manifold. The valve has wet armature type solenoids.

Electrical connections to the valve are made in the electrical wiring housing or by various plug-in devices. A ground terminal is provided.

### APPLICATION GUIDANCE

**Shift Time (Typical)**

For spring offset and spring centered models (rated flow and pressure):

Solenoid Energized
- AC ..... 12 m Sec.
- DC ..... 30 m Sec.

Spring Return
- AC (All spools except 2 and 6) ..... 22 m Sec.
- AC (Type 2 and 6) and DC (All Models) ... 45 m Sec.

Offset to Offset on Spring Centered Models
- AC ..... 25 m Sec.
- DC ..... 60 m Sec.

Maximum Cycling Rate (All spool positions actuated once/cycle)
- .....4 Hz AC .....3 Hz DC

### RATINGS

Maximum Flow ..... 50 l/min. (13 GPM)
Maximum Operating Pressure ("A", "B" and "P" Ports) ..... 350 bar (5000 PSI)
Maximum Tank Line Pressure (5) ..... 155 bar (2250 PSI)
Mounting Pattern ..... ISO 4401-AB-03-4-A, NFPA-DO3 (Formerly DO1) and ANSI-B93.7

### APPLICATION GUIDANCE

**Shift Time (Typical)**

For spring offset and spring centered models (rated flow and pressure):

Solenoid Energized
- AC ..... 12 m Sec.
- DC ..... 30 m Sec.

Spring Return
- AC (All spools except 2 and 6) ..... 22 m Sec.
- AC (Type 2 and 6) and DC (All Models) ... 45 m Sec.

Offset to Offset on Spring Centered Models
- AC ..... 25 m Sec.
- DC ..... 60 m Sec.

Maximum Cycling Rate (All spool positions actuated once/cycle)
- .....4 Hz AC .....3 Hz DC

**Note**

Surges of oil in a common tank line serving these other valves can be of sufficient magnitude to cause inadvertent shifting of these valves. This is particularly critical in the no-spring detented type valves. Separate tank lines or a vented manifold with a continuous downward path to tank is necessary.

Any sliding spool valve, if held shifted under pressure for long periods of time, may stick and not spring return due to fluid residue formation and, therefore, should be cycled periodically to prevent this from happening.

When used as other than a normal four-way valve or other than as shown on the typical graphic symbol chart, consult your local Vickers representative.

### SUBPLATES AND BOLT KITS

Valves, subplates and mounting bolts must be ordered separately.

Example:
- One (1) DG4V-3-2C-M-W-B-40 Valve
- One (1) DGVM-3-10-S Subplate
- One (1) BKDG3-698 (inch) Mounting Bolt Kit †
  - or
- One (1) BKDG3-699M (metric) Mounting Bolt Kit † (Bolt Length = 2.00 inch)
- Bolt Torque ....4.5 to 6.0 Nm (40 to 53 lb. (f) in.)

† See "Bolt Kit" information in Section "O" of Vickers Catalog 400, for bolt thread size and length.

**Adapter Plates**

The DG4V may be mounted in place of the D1L-••-10 series through the use of mounting adapter plate MODAM-10. The overall installation height will increase by 19.1 (.75). Bolts and "O" rings are included with the adapter plate. Accepts inch threads only.

The DG4V can be mounted in place of the DG4S4-01••-50 series through the use of mounting adapter plate DGAM-3-01-10, shown on drawing 517360. The overall installation height will increase by approximately 38 mm (1.5 inches). Bolts and seals are furnished for mounting the adapter plate. (With "A" models, solenoid location is reversed). (2)

**Mounting Face Information**

When mounting on a manifold instead of a subplate, use the dimensions within the shaded area shown on page 4. Mounting face must be flat within 0.013 mm (.0005) and smooth within 1.1 micrometer (45 microinch). Mounting bolts when provided by customer, should be grade 12.9 (SAE grade 7), or better.

### FILTRATION

For satisfactory service life of these components in industrial applications, use full flow filtration to provide fluid which meets ISO cleanliness code 18/15 or cleaner. Selections from Vickers OFP, OFR and OFRS series are recommended. Refer to Section "P"-"Filters" and Section "S"-"Technical Information" of Vickers Catalog 400, or contact your Vickers representative for further filtration advice.

## FLUIDS AND SEALS

Fluorocarbon seals are standard and suitable for use with phosphate ester type fluids or its blends, water glycol, water-in-oil emulsion fluids and petroleum oil. Refer to Vickers data sheet I-286-S, "Hydraulic Fluid and Temperature Recommendations for Industrial Machinery" (included in the Technical Information section of Vickers Catalog 400) for hydraulic fluid and temperature recommendations.

## WEIGHT

DG4V-3-•C/N-M-W•-•-40
Double Solenoid
Models ..... 2.1 kg (4.6 lbs.)
DG4V-3-•A/B/F-M-W•-•-40
Single Solenoid
Models ..... 1.7 kg (3.7 lbs.)

## SERVICE INFORMATION

Refer to specific Vickers part drawing or overhaul manual for service information. A complete "Index to Industrial Products Service Information" is included in the Technical Information Section of Vickers Catalog 400.

Name plate label is asymetrical and fixes the "A" & "B" solenoid arrangement in relation to the "P" port. Designers should note for installation on vertical panels so information can be read right side up.

(2) In right hand assembly, solenoid "A" is always removed. In left-hand assembly solenoid "B" is always removed. See identification plate on top of valve for solenoid identification.

(3) See page 517351-7 for low watt restrictions.

(4) Type #8 spool available only with "-S286" suffix-See note (4) on page 517351-5 for performance restrictions.

(5) See note on page 517351-8 for monitor switch restrictions.

(6) Type #1 spool not available with "Low Watt" (B-9) coil feature.

## MODEL CODE

D G 4 V-3-• • (P) (L)-M (S•) (P••)-••-•-•-(9)-•••-40

[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17]

**[1] Directional Control Valve**

**[2] Manifold or Subplate Mounting**

**[3] Solenoid Operated**

**[4] Rated Pressure 350 bar (5000 PSI)**

**[5] Interface: NFPA-D03 (ISO 4401-03)**

**[6] Type of Spool (Center Condition)**

0 - Open center (all ports).
1 - Open center (P & A to T) (6)
2 - Closed center (all ports).
3 - Closed center (P & B).
6 - Closed center (P only).
7 - Open center (P to A & B) (T Blkd.).
8 - Tandem center (P to T) (4)
11 - Open center (P & B to T).
22 - Closed center (two way).
31 - Closed center (P & A).
33 - Closed center (bleed A & B).

**[7] Spring Arrangement**

A - Spring offset to Port "A" single solenoid.
B - Spring centered - single solenoid.
C - Spring centered - double solenoid.
F - Spring offset - shift to center - single solenoid.
N - No spring detented.

**[8] Manual Operator (In End Cap)**

P - For single sol. models "A", "B" & "F" only.
Omit if not required.

**[9] Left Hand Assembly**

L - For single solenoid models only. (2)
Omit for standard right hand assembly (shown).

**[10] M - Flag (Heading Electrical Features & Options)**

**[11] Monitor Switch Option**

S - Unwired
S1 - Wired N.O.
S2 - Wired N.C. (5)
Omit if not required.

**[12] Electrical Plug-In Options**

PA3 - 3 pin recept. (single sol. models only).
PA5 - 5 pin recept.
PB - "Insta-Plug" (with male & female receptacles)
Omit if not required.

**[13] Electrical Options (Connections, Etc.)**

U - DIN 43650 coils.
W - Wiring housing with 1/2 NPT thread.
WL - Wiring housing with 1/2 NPT thread and sol. ind. lights.

Note: For DIN 43650 plug with indicator lights see 517351-7.

**[14] Coil Identification Letter**

B - 115/120V 60 Hz, 110V, 50 Hz. Indicate other voltages and frequencies by suitable letter (see chart).

**[15] Low Wattage Coil**

9 - Available with "B", 115 Vac 60 Hz coil only. (3) (5)

**[16] Valve Port Orifices**

Applicable ports: "A", "B", "P" & "T".
Sizes designated in mm dia.
Examples of call-out:
- P08 ≅ 0.8 mm dia. orifice in "P" port.
- A10 ≅ 1.0 mm dia. orifice in "A" port.

Note: See page 517351-4 for orifice sizes available.

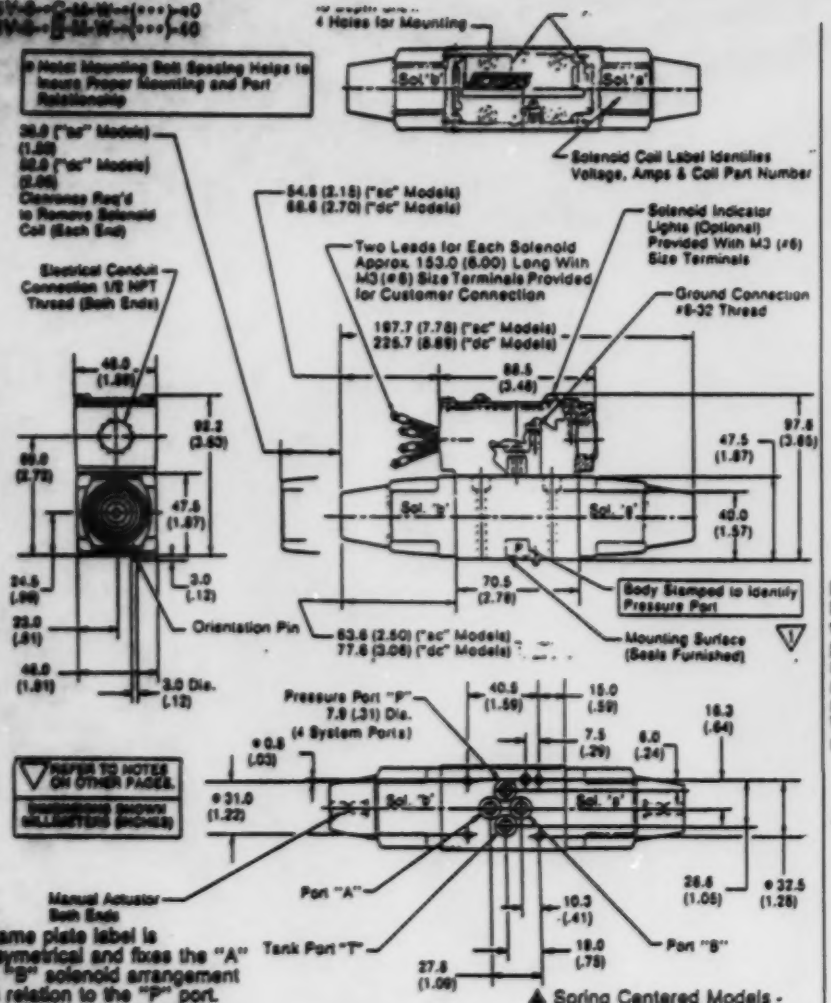
**[17] Design Number**

Subject to change. Installation dimensions remain as shown for design numbers 40 through 49.

5109



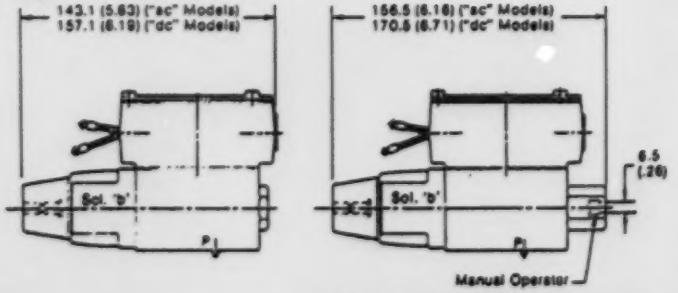
SKETCH NO. A-1098
SHEET C2




▽ Name plate label is asymetrical and fixes the "A" & "B" solenoid arrangement in relation to the "P" port. Designers should note for installation on vertical panels so information can be read right side up.

▲ Spring Centered Models - When solenoid is de-energized the spool is returned to the spring centered position.

▲ MODELS: (SINGLE SOLENOID)
DG4V-3-•A-M-W-•(•••)-40
DG4V-3-•B-M-W-•(•••)-40
DG4V-3-•F-M-W-•(•••)-40
(Right hand assembly shown.)




Note
For "8B" models, the solenoid will be on the right side (above picture) and will be identified as solenoid "b". This is in accordance with the general rule stated on page 5, note ▽. Whenever type 8 spools are used, the solenoids are reversed.

▲ MODELS: (SINGLE SOLENOID MODELS WITH MANUAL OPERATOR IN END CAP - SINGLE SOLENOIDS ONLY)
DG4V-3-•AP-M-W-•(•••)-40
DG4V-3-•BP-M-W-•(•••)-40
DG4V-3-•FP-M-W-•(•••)-40
(Right hand assembly shown.)

▲ Spring Offset Models - When solenoid is de-energized the spool is returned to the spring offset position.

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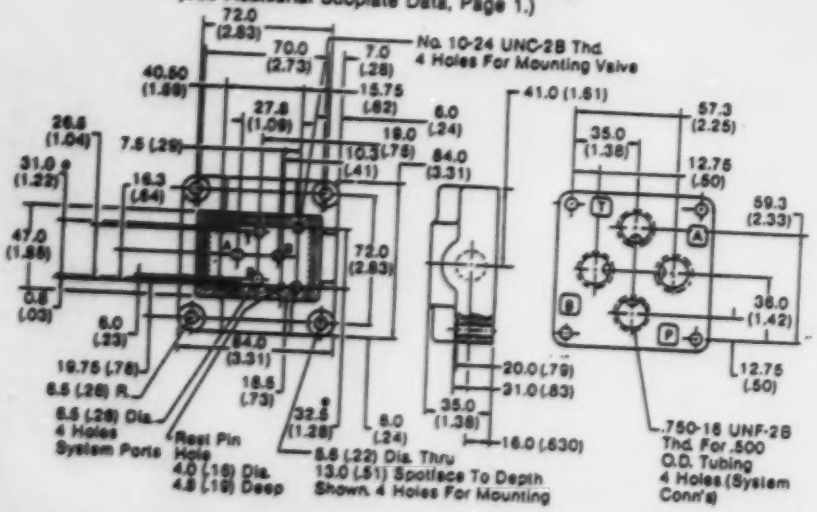
SKETCH NO. A-1098
SHEET C3

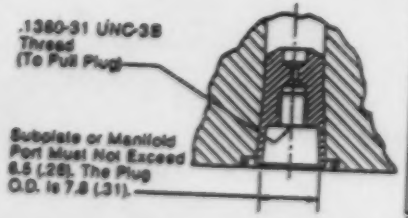
## MOUNTING SUBPLATE - MODEL DGVM-3-10-S
(See Additional Subplate Data, Page 1.)




* Note: Mounting Bolt Spacing Helps To Insure Proper Mounting And Port Relationship

A side port subplate (DGMS-3-1E-10-S) is also available. It is the same size and has the same size ports as the one shown above. Also available is the model DGMS-3-1EY-10-S with .5625-18 UNF-2B st. thd. ports.

## PORT RESTRICTOR PLUGS
TYPICAL MODEL DG4V-3-***-M-**P08-40
(0.8 mm Dia. Orifice in 'P' Port)




Restrictor plugs are available for use in "A", "B" or "T" ports. They are used to restrict flow or for circuit dampening.

| Part No. | Orifice Dia. | Model Code |
|---|---|---|
| 631892 | 0.76 (.030) | *08 |
| 628733 | 1.02 (.040) | *10 |
| 632937 | 1.27 (.050) | *13 |
| 635281 | 1.50 (.060) | *15 |
| 631931 | 2.29 (.090) | *23 |
| 632936 | Blank | *00 |

Note: *-Port "A", "B", "P" or "T"

## FUNCTIONAL SYMBOLS
(Cross Over Conditions)

Single Solenoid valves, solenoid at port A end

DG4V-3-*A valves

0 = 2 = 6 = 7 = 22 =

DG4V-3-*B valves

0 = 1 = 2 = 3 = 6 = 7 = 11 = 31 = 33 =

DG4V-3-*BL(-*) valves

8 =

DG4V-3-* F valves

0 = 1 =

2 = 3 = 6 = 7 = 11 = 31 = 33 =

DG4V-3-*FL valves

8 =

Single solenoid valves, solenoid at port B end

DG4V-3-*AL(-*) valves

0 = 2 = 6 = 7 = 22 =

DG4V-3-*BL(-*) valves

0 = 1 = 2 = 3 =

6 = 7 = 11 = 31 = 33 =

DG4V-3-*BB(-*) valves

8 =

DG4V-3-*FL valves

0 = 1 = 2 = 3 = 6 = 7 = 11 = 31 = 33 =

DG4V-3-*F valves

8 =

▲ Transient condition only.

Double solenoid valves, spring centered

DG4V-3-*C(-*) valves

0 = 1 = 2 = 3 = 6 = 7 = 8 = 11 = 31 = 33 =

Double solenoid valves, two-position detented

DG4V-3-*N(-*) valves

0 = 2 = 6 =

SKETCH NO. A-1098
SHEET C4

## FLOW RATING & GRAPHIC SYMBOLS

**Standard Spool Types (Center or Cross-Over Condition)**

| Valve Type | Graphic Symbol | Open Center All Ports "0" | Open Center "P" & "A" to Tank, "B" Blocked "1" | Closed Center All Ports "2" | Closed Center "A" Open to "T", "P" & "B" Blocked "3" | Close Center "A" & "B" Open to "T" "P" Blocked "6" | Open Center "P" Open to "A" & "B" "T" Blocked "7" | Tandem Center "P" Open to "T" "A" & "B" Blocked "8" | Open Center "P" & "B" to Tank "A" Blocked "11" | Closed Center "B" Open to "T", "P" & "A" Blocked "31" | Closed Center "A" & "B" Open to "T" Over Tapers, "P" Blocked "33" | Recommended Flow @ 250 bar (5000 PSI) L/Min. (GPM) | Maximum Flow Without Malfunction @ 250 bar (5000 PSI) L/Min. (GPM) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spring Offset Two Way "22A" "*A" | | | | DG4V-3-22A | | | | | | | | 3.8 (1.0) | 5.7 (1.5) |
| | | DG4V-3-0A | | | | | | | | | | 9.5 (2.5) | 13.3 (3.5) |
| | | | | DG4V-3-2A | | DG4V-3-6A | | | | | | 19 (5) | 38 (10) |
| | | | | | | | DG4V-37A | | | | | | 38 (10) |
| Spring Offset with Manual Override in End Cap Two Way "22AP" "*AP" | | | | DG4V-3-22AP | | | | | | | | 3.8 (1.0) | 5.7 (1.5) |
| | | DG4V-3-0AP | | | | | | | | | | 9.5 (2.5) | 13.3 (3.5) |
| | | | | DG4V-3-2AP | | DG4V-3-6AP | | | | | | 19 (5) | 38 (10) |
| | | | | | | | DG4V-37AP | | | | | | 38 (10) |
| Spring Centered Single Solenoid "*B" | | DG4V-3-0B | | DG4V-3-2B | | | | | | | | | 80 (13) |
| | | | | | | DG4V-3-6B | DG4V-3-7B | | | | DG4V-3-33B | 19 (5) | 38 (10) |
| | | | DG4V-3-1B | | DG4V-3-3B | | | | DG4V-3-11B | DG4V-3-31B | | | 38 (10) |
| Spring Centered Single Solenoid with Man. Oper. in End Cap "*BP" | | DG4V-3-0BP | | DG4V-3-2BP | | | | | | | | | 80 (13) |
| | | | | | | DG4V-3-6BP | DG4V-3-7BP | | | | DG4V-3-33BP | 19 (5) | 38 (10) |
| | | | DG4V-3-1BP | | DG4V-3-3BP | | | | DG4V-3-11BP | DG4V-3-31BP | | | 38 (10) |
| Spring Centered "*C" | | DG4V-3-0C | | DG4V-3-2C | | | | | | | | | 80 (13) |
| | | | | | | DG4V-3-6C | DG4V-3-7C | | | | DG4V-3-33C | 19 (5) | 38 (10) |
| | | | DG4V-3-1C | | DG4V-3-3C | | | | DG4V-3-11C | DG4V-3-31C | | | 38 (10) |
| Spring Offset Both to Center "*F" | | DG4V-3-0F | DG4V-3-1F | DG4V-3-2F | DG4V-3-3F | DG4V-3-6F | DG4V-3-7F | | DG4V-3-11F | DG4V-3-31F | DG4V-3-33F | 19 (5) | 38 (10) |
| Spring Offset Both to Center with Man. Oper. in End Cap "*FP" | | DG4V-3-0FP | DG4V-3-1FP | DG4V-3-2FP | DG4V-3-3FP | DG4V-3-6FP | DG4V-3-7FP | | DG4V-3-11FP | DG4V-3-31FP | DG4V-3-33FP | 19 (5) | 38 (10) |
| No Spring Detented "*H" | | DG4V-3-0H | | DG4V-3-2H | | DG4V-3-6H | | | | | | 19 (5) | 80 (13) |

——→ FREE FLOW —||→ RESTRICTED FLOW

(1) NOTE: On all models when solenoid "A" is energized, flow is always P→ A. When solenoid "B" is energized, flow is always P→ B. This is in accordance with the ANSI-B93.9 standard. Solenoid "A" & "B" are identified on the identification plate on the top of the valve's wiring box. Single solenoid models can be assembled left-hand (flow is P→ A when solenoid "A" is energized.)

(2) Maximum flow without malfunction for "OA(P)" spool can be increased by reducing pressure as follows:
19 L/min. (5 GPM) @ 210 bar (3000 PSI)
38 L/min. (10 GPM) @ 140 bar (2000 PSI)

(3) Maximum Flow without malfunction for "22A(P)" spool can be increased by reducing pressure as follows:
11.4 L/min. (3.0 GPM) @ 210 bar (3000 PSI)
13.3 L/min. (3.5 GPM) @ 140 bar (2000 PSI)
15.1 L/min. (4.0 GPM) @ 70 bar (1000 PSI)

(4) Spool Type "9C-S288" is limited to 19 L/min. (5 GPM) & 210 bar (3000 PSI) maximum. (P——→ T) pressure is limited to the tank port rating of 155 bar (2250 PSI).

(5) See Page 517351-8 for monitor switch model restriction.

I-517351-E



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SKETCH NO. A-1098
SHEET C5

## PRESSURE DROP

**PRESSURE DROP CURVE REFERENCE CHART**

| Spool Type & Center Position | P→A | B→T | P→B | A→T | P → T at Center |
|---|---|---|---|---|---|
| "08" "0C" "0F" | (3) | (3) | (2) | (3) | (3) |
| ▽4 "18" "1C" "1F" | (3) | (4) | (3) | (3) | (3) |
| "28" "2C" "2F" | (3) | (4) | (3) | (4) | — |
| "38" "3C" "3F" | (3) | (4) | (3) | (3) | — |
| "88" "8C" "8F" | (4) | (2) | (4) | (2) | — |
| "78" "7C" "7F" | (1) | (4) | (1) | (4) | — |
| ▽4 "88" "8C" "8F" | (2) | (3) | (2) | (3) | (5) |
| "118" "11C" "11F" | (3) | (3) | (3) | (4) | (3) |
| "218" "21C" "21F" | (3) | (3) | (3) | (4) | — |
| "238" "23C" "23F" | (3) | (3) | (3) | (3) | See "•" Note |
| "8A" "8F" "8W" | (3) | (3) | (3) | (3) | (4) — — — |

1. The pressure drop curves give approximate pressure drop (△P) when passing 21 cSt (100 SUS) fluid(s) having .865 specific gravity.

2. For any other viscosity(s) the pressure drop ( △P) will change as follows:

| Viscosity(s) cSt (SUS) | 14 (75) | 32 (150) | 43 (200) | 54 (250) | 65 (300) | 76 (350) | 86 (400) |
|---|---|---|---|---|---|---|---|
| % of △P (Approx.) | 93 | 111 | 119 | 126 | 132 | 137 | 141 |

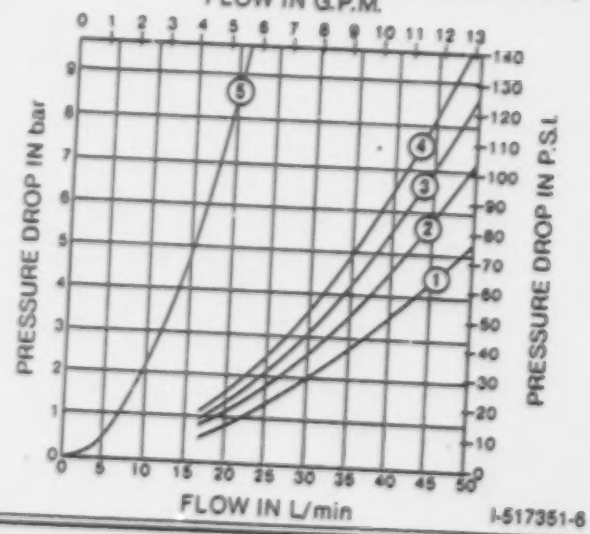
3. For any other specific gravity▲($G_1$) the pressure drop ( $\triangle P_1$) will be approximately:
$\triangle P_1 = \triangle P\ (G_1/G)$

▲ Specific gravity of fluid may be obtained from its producer. The value is higher for fire-resistant fluids than for oil.

Example:
Find the pressure drop from "P" to "B" for type '2C' spool. Using table (left) find '2C' in spool type column. To the right, find the reference curve number (3) under "P" to "B" column. The pressure drop from "P" to "B" for type '2C' spool would be obtained on curve number 3.

"•" Note: Type "33" spool at center will pass 7.6 L/min. (2 GPM) to 17.0 L/min. (4.5 GPM) at 103 bar (1500 PSI) inlet pressure.

**PRESSURE DROP CURVES FOR APPROXIMATE (△P)**
**Using 20.5 cSt (100 SUS) Fluids Having 0.87 Specific Gravity**






SKETCH NO. A-1098
SHEET C6

## ECTRICAL INFORMATION

solenoids furnished with this ve are dual frequency types. shown in the table below. ey also resist burnout, which ows time to find and correct oblems before solenoid rn-out occurs.

Solenoids are identified by a letter in the model number.
Example:
DG4V-3-2C-M-W-B-40

| Solenoid Voltage Rating | | Identification Letter | Inrush • amps (R.M.S.) | Holding amps | Holding watts | Resistance ohms @ 20° C | Inductance mH |
|---|---|---|---|---|---|---|---|
| 115/120 Vac 60 Hz<br>110 Vac .50 Hz | | B • | 2.0 | 0.54<br>0.64 | 31 | 33.5 | 185 |
| 230/240 Vac 60 Hz<br>220 Vac .50 Hz | | D • | 1.0 | 0.27<br>0.32 | 31 | 140 | 731 |
| 24 Vac | 60 Hz<br>50 Hz | N • | 7.8<br>8.4 | 2.45<br>3.15 | 27<br>35 | 1.6 | 57 |
| ⚠3 115/120 Vac 60 Hz<br>110 Vac .50 Hz | | B-9<br>(Low Watt) | 1.5 | 0.31<br>0.37 | 17<br>21 | 55.0 | 285 |
| 100 Vac | 60 Hz<br>50 Hz | T | 1.9<br>2.1 | 0.66<br>0.85 | 27<br>35 | 23.1 | 150 |
| 6 V dc | | F | — | 6.8 | 41 | 0.88 | 4.07 |
| 12 V dc | | G • | — | 3.5 | 41 | 3.45 | 16.3 |
| 24 V dc | | H • | — | 1.7 | 41 | 13.9 | 64.6 |
| 32 C dc | | DK | — | 1.3 | 41 | 24.7 | 114 |
| 48 V dc | | J | — | 0.87 | 41 | 55.3 | 258 |

⚠3 Valve Models using the low watt "B-9" solenoid are limited to 19 L/min (5 GPM) and 140 bar (2000 PSI) maximum.

Note: Solenoids are designed to function continuously at ± 10 percent of the rated voltage.
• Maximum peak inrush amps approximately 1.4 x R.M.S. value shown.
■ See Div. standard solenoids information at right.

### Solenoid Energizing

Spring centered and spring offset types will be spring positioned unless solenoid is energized continuously. No-spring detented valves may be energized momentarily approximately 0.1 second; when solenoid is de-energized spool will remain in last position attained provided there is no severe shock, vibration or unusual pressure transients.

### Electrical Connection

1/2 NPT thread for DG4V-3-••-M-W-••-40 models are provided on both ends of the terminal box. The terminal box is a NEMA type 4 enclosure.

The conduit connection readily adapts to connector-receptacle assemblies on the market.

### Solenoid Indicator Lights

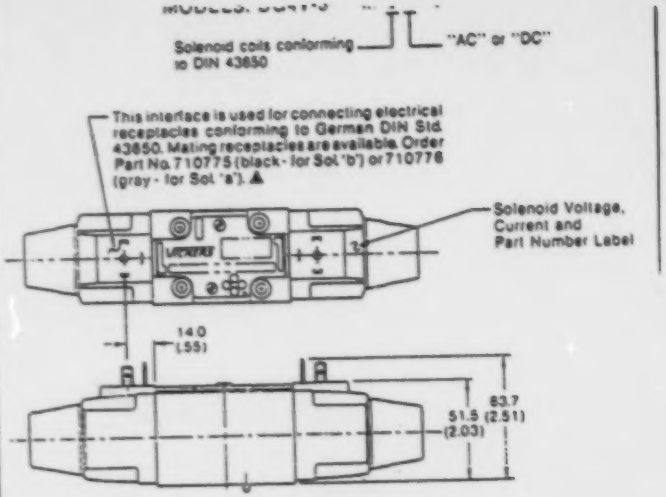
Light is "on" when there is current at the solenoid coil. Lights are available for various voltages in both AC and DC service.

### Canadian Standards Association Certification

Valves with solenoid letter codes B, D, G, H & N have Canadian standards certification. Identify by adding the -S324 suffix in the model code. This certification does not include models with indicator lights (L) or plug-in devices (PA•/PB) or DIN 43650 plugs.

### Lead Wire Insulation

Class "H" on both AC and DC solenoid lead wires.

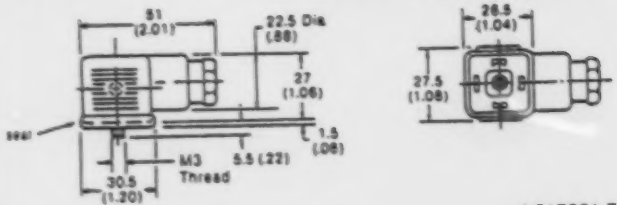

Solenoid coils conforming to DIN 43650
"AC" or "DC"
This interface is used for connecting electrical receptacles conforming to German DIN Std. 43650. Mating receptacles are available. Order Part No. 710775 (black - for Sol. 'b') or 710776 (gray - for Sol. 'a'). ▲
Solenoid Voltage, Current and Part Number Label
14.0 (.55)
63.7
51.5 (2.51)
(2.03)

### ▲Plug Connector
(DIN 43650)
(Order separate of valve)

Means of connection:
screw terminals
Conductor cross-sectional area:
0.5 .....1.5 mm²
Cable collar thread: Pg 11
Cable diameter: 6 .....10 mm

### Note
Connectors with indicator lights are available: (order separate of valve)

| Voltage | Gray - 'A' Sol. | Black - 'B' Sol. |
|---|---|---|
| 12-24 | 977467 | 977466 |
| 100-125 | 977469 | 977468 |
| 200-240 | 977471 | 977470 |




I-517351-7

Revised 4-87



SKETCH NO. A-1098
SHEET C7

## MONITOR SWITCH OPTION

Cherry switch, Und. Lab. Listed, 11A, 1/4 H.P. 125/250 V.A.C.

**Note**

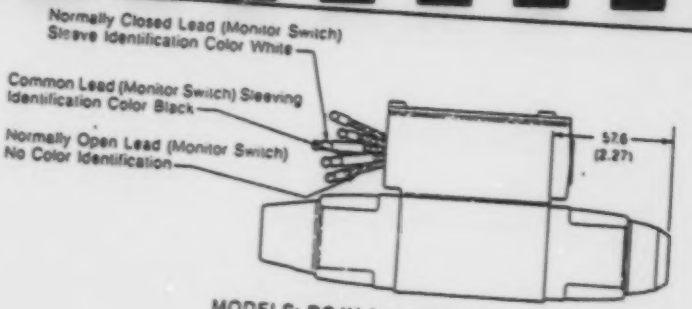
Integral monitor switch permits electrical monitoring of valve spool position and may be wired into control circuit to indicate valve function. For current load vs. life expectancy for the Cherry switch # E923-S1AA contact switch manufacturer.

**5 Valve Rating**

The tank pressure should not exceed 200 P.S.I. and the valve should not be used above 8 G.P.M. flow.

Monitor switch does not provide for manual override operation.

Monitor switch feature is not available on models with manual operator in end cap (•P). Wired monitor switch feature ("S1" and "S2") is available on models with "PA3", "PA5" or "PB" electrical plug-in features.


Normally Closed Lead (Monitor Switch) Sleeve Identification Color White
Common Lead (Monitor Switch) Sleeving Identification Color Black
Normally Open Lead (Monitor Switch) No Color Identification
57.6 (2.27)

MODELS: DG4V-3-•••-MS-W•-••••-40

Monitor Switch: "S" Unwired
"S1" - Wired N.O.
"S2" - Wired N.C.

## INSTA-PLUG OPTION

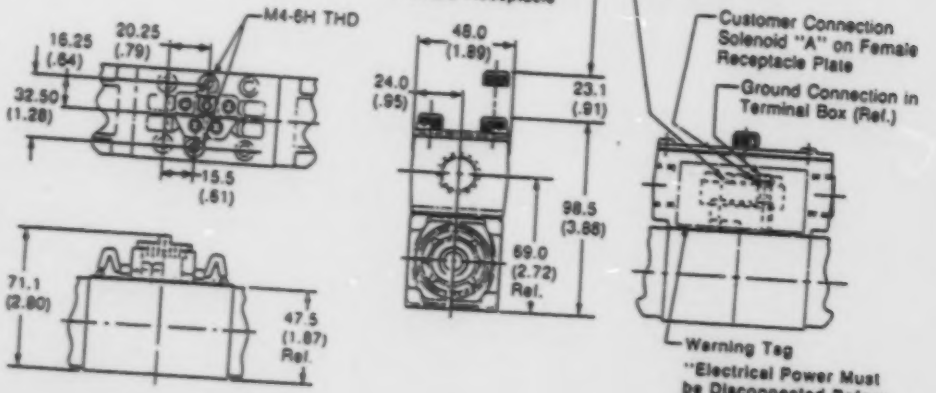
Vickers "Insta-Plug" provides a means of disconnecting electrical power to the valve without actually breaking individual wire connections. The male half of the plug is attached to the top of the valve body. Solenoid leads are connected to this half of the plug by Vickers. The mating plug is attached inside the wire housing. Terminals are provided on top of it for the convenience of connecting machine wires.

Two thumb screws are used to hold the wiring housing with the female plug half to the valve. These screws are captive to avoid loss on servicing. To disconnect the valve they are loosened until clear, allowing the wiring housing to be pulled away from the valve body; thereby disconnecting electrical power to the valve. Note that the ground fifth post is longer than the other four, providing a first-make/last-break ground feature.

The PB configuration includes both the male and female (retained in the wiring housing) halves for a complete plug-in unit.

Solenoid indicator lights can also be furnished with the Insta-Plug feature. When furnished, the lights are pre-wired to the female half of the plug. Solenoids "A" and/or "B" are identified on the identification plate attached to the wiring housing.

MODELS: DG4V-3-•••-M-PB-W•-40




I-517351-8



SKETCH NO. A-1098
SHEET C8

'ANDARD T3.5.29-1980
e receptacle is a standard
ee or five pole electrical
nnector with shortened leads
d terminals added. the five
le plug has four leads 101.6
.0") long and one 177.8 (7.0")
g. The No. 4 and No. 2 leads
e attached to the "A" solenoid
d the No. 5 and No. 1 leads
e attached to the "B" solenoid.
lonitor switch models not
cluded). The three pole plug
s two leads 101.6 (4.0") long
d one 177.8 (7.0"). The No. 2
d No. 3 leads are attached to
e solenoid. All of the wires
ve underwriters recognized
on-solder insulated eyelet
rminals. The green wire is used
r the ground connection (No. 8
rew furnished). Valves are
pplied pre-wired as follows:

- 3 Pole Single Solenoid Models
- 5 Pole Single Solenoid Models
- C - 5 Pole Double Solenoid Models
- D - 5 Pole Single Solenoid & Monitor Switch Models (Wired Normally Open)
- E - 5 Pole Single Solenoid & Monitor Switch Models (Wired Normally Closed)

### Models with Solenoid Indicator Lights

Receptacle will be prewired to the solenoid eyelets & the indicator light eyelets. The connection will be made via No. 6 screws & nuts insulated with shrink sleeve tubing.

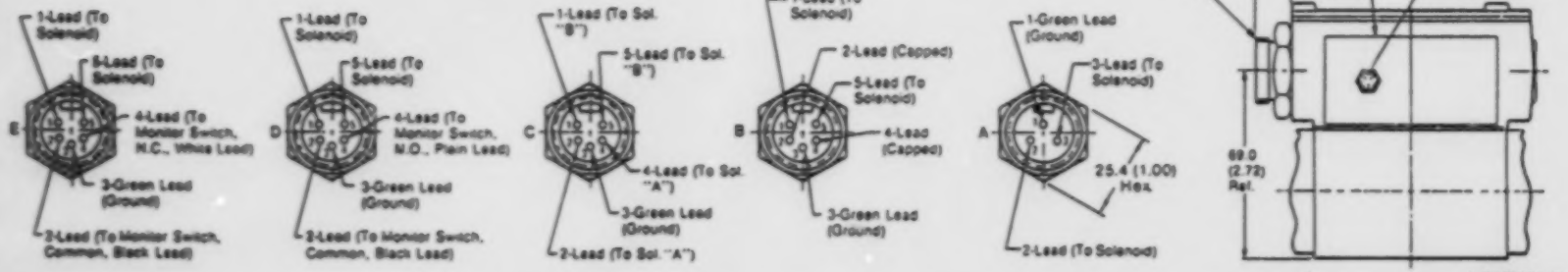
### Models Without Solenoid Indicator Lights

Receptacle will be prewired to the solenoid eyelets. The connection will be made via No. 6 screws and nuts insulated with shrink sleeve tubing.

The female portable plug to be furnished by customer.

MODELS: DG4V-3-···-MPA··W-····-40

Electrical Plug Feature
"PA3" - NFPA 3 Pin Conduit Connector
"PA5" - NFPA 5 Pin Conduit Connector




I-517351-9

Revised 4-87

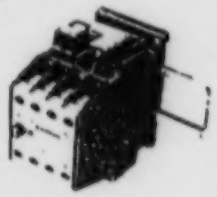
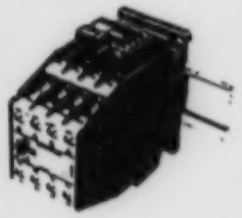
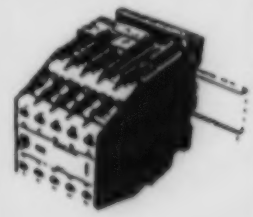
SKETCH NO. A-1098
SHEET C9

3TH

# Industrial Relays

(PRIME MOVER POWER CONTACTOR)

## AC/DC Heavy-Duty Types
## AC-Operated

| Selection and Prices<br>Max. 600V AC/DC | Number of Poles | Contact Reference ① | Contact Arrangement: Normal NO | Normal NC | Overlap NO | Overlap NC | Type-Number ③ | Open Type Price | Enclosed Types ② General Purpose EEMAC 1 | Enclosed Types ② General Purpose Price |
|---|---|---|---|---|---|---|---|---|---|---|
|  3 TH 80 | 4-Pole | 40E | 4 | 0 | — | — | 3 TH 8040 — 0A .. | $54 | -C1 | $80 |
| | | 31E | 3 | 1 | — | — | 3 TH 8031 — 0A .. | | -C1 | |
| | | 22E | 2 | 2 | — | — | 3 TH 8022 — 0A .. | | -C1 | |
| | | 13E | 1 | 3 | — | — | 3 TH 8013 — 0A .. | | -C1 | |
| | | 04E | 0 | 4 | — | | 3 TH 8004 — 0A .. | | -C1 | |
| | | 31U | 2 | 0 | 1 | 1 | 3 TH 8095 — 0A .. | | -C1 | |
| | | 22U | 1 | 1 | 1 | 1 | 3 TH 8096 — 0A .. | | -C1 | |
| | | 202U | 0 | 0 | 2 | 2 | 3 TH 8092 — 0A .. | | -C1 | |
|  3 TH 82 | 8-Pole | 80E | 8 | 0 | — | — | 3 TH 8280 — 0A .. | 80 | -C1 | 104 |
| | | 71E | 7 | 1 | — | — | 3 TH 8271 — 0A .. | | -C1 | |
| | | 62E | 6 | 2 | — | — | 3 TH 8262 — 0A .. | | -C1 | |
| | | 53E | 5 | 3 | — | — | 3 TH 8253 — 0A .. | | -C1 | |
| | | 44E | 4 | 4 | — | — | 3 TH 8244 — 0A .. | | -C1 | |
| | | 44U | 3 | 3 | 1 | 1 | 3 TH 8293 — 0A .. | | -C1 | |
|  3 TH 83 | 10-Pole | 100E | 10 | 0 | — | — | 3 TH 8310 — 0A .. | 128 | -C1 | 152 |
| | | 91E | 9 | 1 | — | — | 3 TH 8391 — 0A .. | | -C1 | |
| | | 82E | 8 | 2 | — | — | 3 TH 8382 — 0A .. | | -C1 | |
| | | 73E | 7 | 3 | — | — | 3 TH 8373 — 0A .. | | -C1 | |
| | | 64E | 6 | 4 | — | — | 3 TH 8364 — 0A .. | | -C1 | |
| | | 55E | 5 | 5 | — | — | 3 TH 8355 — 0A .. | | -C1 | |
| | | 55U | 4 | 4 | 1 | 1 | 3 TH 8394 — 0A .. | | -C1 | |

### ③Coil Voltage / Frequency Suffix

The Type-Number as listed is not complete. To complete the Type-Number, replace the dots at the end with a voltage and frequency identification number selected from the table below

| Hertz | Volts | | | | | | |
|---|---|---|---|---|---|---|---|
| | 24 | 115 | 230 | 380 | 400 | 460 | 575 |
| 60 | C1 | J1 | L1 | — | Q0 | — | S1 |
| 50 | C1 | J1 | L1 | Q0 | — | S1 | — |

If voltage and suffix cannot be determined from the table above, refer to Siemens.

The relays will operate reliably on 60 Hz if the coil excitation voltage is within 80 to 110% of rated coil voltage.

① Contact reference, marked on relay.
② For other enclosures refer to Siemens

■ Dimensions - see page 32.
■ To order - complete Type-Number,
- state suffix for coil voltage or
- state suffix for enclosed type

SKETCH NO. A-1098
SHEET D1

# Industrial Relays

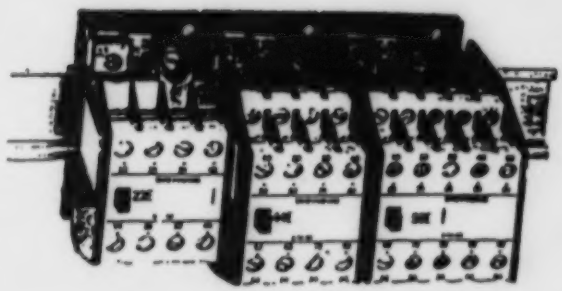
**3 TH**

## AC/DC Heavy-Duty Types

### Application

The 3 TH Heavy Duty Relays are primarily used in machine tools and generally in industrial control applications where compactness, dependability and overall endurance of relays are essential.

These Relays are designed for 600V AC/DC switching and for either AC or DC coil operation.
The 3 TH Relays are available in basic 4-, 8- and 10-pole design.



### Features

Clear Contact Terminal designation according to international standards.
High Mechanical and Electrical Life.
High Switching Frequency.
Compact, space saving design.
Suitable for base mounting or mounting on standard 35 mm rail.
Straight-through wiring.
Standard climate proof design (tropicalized).
Completely enclosed contacts, coil and magnetic system.

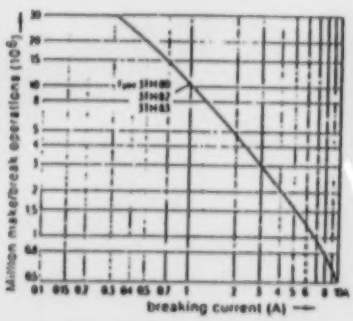
### Life Expectancy

### Mechanical Life

The Mechanical Life of 3 TH Heavy Duty Relays is over 30 million operations.

### Electrical Life of Contacts

Similar to the 3 TB contactors these relays "close" virtually bounce free. As a result, the contact life is mainly determined by the breaking current. The graph shows the relationship between the breaking-current and the Electrical Life in millions of switching cycles.




Contact life versus breaking current

### Approvals

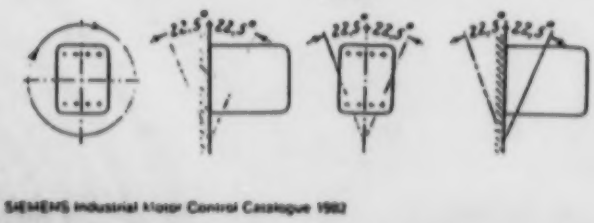
Siemens 3 TH Heavy Duty Industrial Relays are approved by (GL) as well as by all major standardisation organizations throughout the world.

### Mounting

The 3 TH relays should be mounted in vertical position. The support structure may have a tilt of 22.5° maximum from the vertical.

AC-operated relays may be mounted in any desired position.

DC-operated relays should be mounted in such a position that an inclination of more than 22.5° to the vertical is avoided.




### Technical Data

**A.C. Contact Rating — Heavy Duty**

| A.C. Ratings — EEMAC A600 | | | | | |
|---|---|---|---|---|---|
| Inductive Power Factor = 0,35 | | | | | |
| Volts | Make | | Break | | Continuous Amperes |
| | Amps. | VA | Amps. | VA | |
| 120 | 60 | 7200 | 6 | 720 | 10 |
| 240 | 30 | 7200 | 3 | 720 | 10 |
| 480 | 15 | 7200 | 1.5 | 720 | 10 |
| 600 | 12 | 7200 | 1.2 | 720 | 10 |

**D.C. Contact Rating — Standard Duty**

| D.C. Ratings — EEMAC P600 | | |
|---|---|---|
| Volts | Make and Break Amperes | Continuous Amperes |
| 125 | 1.1 | 5 |
| 250 | 0.55 | 5 |
| 600 | 0.2 | 5 |

**Operating Times**

| | | |
|---|---|---|
| AC - Operated | | |
| Make | ms | 8 - 24 |
| Break | ms | 5 - 22 |
| Arc Duration | ms | 10 |
| DC - Operation | | |
| Make | ms | 40 - 90 |
| Break | ms | 35 - 85 |
| Arc Duration | ms | 10 |

For further details — refer to Siemens
Maximum Switching frequency — 3000 operations/hour.

**Magnetic Coil Power Consumption**

| | | |
|---|---|---|
| AC - Operated | | |
| momentarily during closing | VA | 68 |
| continuously after closing | VA | 9 |
| DC - Operated | | |
| momentarily during closing | W | 8.5 |
| continuously after closing | W | 8.5 |



SKETCH NO. A-1098
SHEET D2

## Multimate Contacts

For use in:
"M" Series Connectors
Series 1 and 4 CPC Connectors
Metrimate Connectors
"G" Series Connectors

Dimensioning:
All dimensions in inches and millimetres. Values in brackets are metric equivalents.
Chart contains dimensions in inches over millimetres.

### Type III+

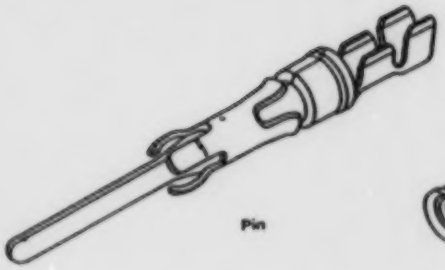
Contact Size — 16
Pin Diameter — .062 [1.57]
Test Current — 13 Amperes†

**Material:**
Contact Body — Brass
Spring — Stainless Steel

**Finish:**
See chart below.

[Refer to contact current carrying capability information, page 111.

AMP Extraction Tool No. 305183




| Wire Size Range* AWG | Wire Size Range* [mm²] | Ins. Dia. Range | Contact Finish | Strip Form Contact No.* Pin | Strip Form Contact No.* Socket | Loose Piece Contact No. Pin | Loose Piece Contact No. Socket | Tooling No. Strip Form Miniature Applicator | Tooling No. Loose Piece Hand Tool |
|---|---|---|---|---|---|---|---|---|---|
| 30-26 | 0.05-0.15 | .070-.100 1.78-2.54 | Gold/Nickel* | 66477-1 | 66479-1 | 66643-1 | 66483-1 | 466054-2 | 90282-1 |
| | | .040-.060 1.02-1.52 | Gold/Nickel* | 66425-5 | 66424-5 | 66429-1 | 66428-1 | 687193-3 | 90066 |
| | | | Tin | 66425-6 | 66424-6 | 66429-2 | 66428-2 | | |
| | | | Gold/Nickel* | 66425-7 | 66424-7 | 66429-3 | 66428-3 | | |
| | | | Sel. Gold/Nickel* | 66425-8 | 66424-8 | 66429-4 | 66428-4 | | |
| | | .014-.03C 0.36-0.76 | Gold/Nickel* | 66383-5 | 66384-5 | 66406-1 | 66405-1 | 466365-2 | 90275-2 |
| | | | Tin | 66383-6 | 66384-6 | 66406-2 | 66405-2 | | |
| | | | Gold/Nickel* | 66383-7 | 66384-7 | 66406-3 | 66405-3 | | |
| | | | Sel. Gold/Nickel* | 66381-8 | 66384-8 | 66406-4 | 66405-4 | | |
| 26-24 | 0.12-0.2 | .035-.055 0.89-1.4 | Gold/Nickel* | 66106-5 | 66108-5 | 66107-1 | 66109-1 | 466321-2 | 90277-1* or 90066 |
| | | | Tin | 66106-6 | 66108-6 | 66107-2 | 66109-2 | | |
| | | | Gold/Nickel* | 66106-7 | 66108-7 | 66107-3 | 66109-3 | | |
| | | | Sel. Gold/Nickel* | 66106-8 | 66108-8 | 66107-4 | 66109-4 | | |
| 24-20 | 0.2-0.6 | .040-.060 1.02-2.03 | Gold/Nickel* | 66102-6 | 66104-6 | 66103-1 | 66105-1 | 466323-2 | 90277-1,* 90066 or 90067 |
| | | | Tin | 66102-7 | 66104-7 | 66103-2 | 66105-2 | | |
| | | | Gold/Nickel* | 66102-8 | 66104-8 | 66103-3, | 66105-3 | | |
| | | | Sel. Gold/Nickel* | 66102-9 | 66104-9 | 66103-4 | 66105-4 | | |
| | | .080-.100 2.03-2.54 | Tin | 66332-5 | 66331-5 | 66400-1 | 66399-1 | 466324-2 | 90277-1,* 90067-2 or 90725-2 |
| | | | Gold/Nickel* | 66332-6 | 66331-6 | 66400-2 | 66399-2 | | |
| | | | Gold/Nickel* | 66332-7 | 66331-7 | 66400-3 | 66399-3 | | |
| | | | Sel. Gold/Nickel* | 66332-8 | 66331-8 | 66400-4 | 66399-4 | | |
| | | .060-.133 1.52-3.43 | Gold/Nickel* | 66564-5 | 66563-5 | 99566-1 | 66565-1 | 466383-2 | 90331-1 |
| | | | Tin | 66564-6 | 66563-6 | 66566-2 | 66565-2 | | |
| | | | Gold/Nickel* | 66564-7 | 66563-7 | 66566-3 | 66565-3 | | |
| | | | Sel. Gold/Nickel* | 66564-8 | 66563-8 | 66566-4 | 66565-4 | | |
| 18-16 | 0.8-1.4 | .083-.100 2.03-2.54 | Gold/Nickel* | 66098-6 | 66100-6 | 66099-1 | 66101-1 | 466325-2 | 90277-1,* 90067, 90208-1 or 90067-2 |
| | | | Tin | 66098-7 | 66100-7 | 66099-2 | 66101-2 | | |
| | | | Gold/Nickel* | 66098-8 | 66100-8 | 66099-3 | 66101-3 | | |
| | | | Sel. Gold/Nickel* | 66098-9 | 66100-9 | 66099-4 | 66101-4 | | |
| 15-14** | 0.8-2 | .110-.150 2.79-3.81 | Tin | 66397-1 | 66396-1 | 66802-1 | 66801-1 | 466732-2 | 90310-2 |
| | | | Sel. Gold/Nickel* | 66397-2 | 66396-2 | 66802-2 | 66801-2 | | |
| 14 | 2 | .060-.100 2.03-2.54 | Gold/Nickel* | 66359-5 | 66358-5 | 66361-1 | 66360-1 | 466326-2 | 90208-1 |
| | | | Tin | 66359-6 | 66358-6 | 66361-2 | 66360-2 | | |
| | | | Gold/Nickel* | 66359-9 | 66358-9 | 66361-3 | 66360-3 | | |
| | | | Sel. Gold/Nickel* | 1-66359-0 | 1-66358-0 | 66361-4 | 66360-4 | | |

*Wire strip length — .156 [3.96] (all wire sizes).

*.000030 [0.00076] gold over .000050 [0.00127] nickel.

†.000015 [0.00038] gold over .000050 [0.00127] nickel.

*Gold flash over .000050 [0.00127] nickel on entire contact, with .000030 [0.00076] gold on electrical engagement area.

*Strip form contacts are rooted for AMP miniature applicator and AMP-O-MATIC Side-Feed Stripper/Crimper Machine.

†Economy hand tool.

**In CPC Connectors use these contacts only for Series 1 connector (Arrangement No. 23-24) and Series 4 connectors (Arrangement Nos. 23-16M and 23-22M).

Insertion Tool No. 91008-1 (for insulation diameters .070 [1.78] or less).

Extraction Tool No. 305183.

Dimensioning:
All dimensions in inches and millimetres.
Values in brackets are metric equivalents.
Chart contains dimensions in inches over millimetres.

## Type XII Contacts

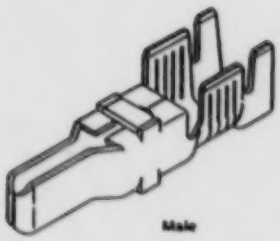
For use in:
"M" Series Connectors
Series 3 and 4 CPC Connectors
"G" Series Connectors

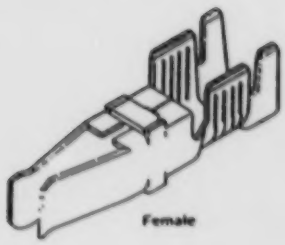
**Test Current — 35 Amperes†**

**Material:**
Copper

**Finish:**
See chart below.

†Refer to contact current carrying capability information, page 111.


Male


Female

AMP Extraction Tool No. 91019-3

| Wire Size Range* AWG | Wire Size Range* [mm²] | Ins. Dia. Range | Contact Finish | Strip Form Contact No. For Standard Applicator: Male | Strip Form Contact No. For Standard Applicator: Female | Strip Form Contact No. For Miniature Applicator: Male | Strip Form Contact No. For Miniature Applicator: Female | Application No. Standard | Application No. Miniature | Loose Piece Contact No. Male | Loose Piece Contact No. Female | Crimping Tools: Economy Hand Tool | Crimping Tools: Die Insert No. for Hand Tool 69710-1 or Pneumatic Tool 69365 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 and 14-12 | 1.25-1.4 and 2-3 | .135-.160 [3.43-4.06] | Set Gold/Nickel‡ | 66255-2 | 66252-2 | 66255-6 | 66252-6 | 565612-2, 565616-2 | 466425-2 | 66261-2 | 66258-2 | 90382-2 | 90145-1* and 90145-2* |
| | | | | 66256-2** | — | 66256-4** | — | | | 66262-2** | — | | |
| | | | | 66329-2*** | — | — | — | | | 66330-2*** | — | | |
| | | | Set Gold/Nickel‡ | 66255-3 | 66252-3 | 66255-4 | 66252-5 | | | 66261-3 | 66258-3 | | |
| | | | | 66256-3** | — | — | — | | | 66262-3** | — | | |
| | | | | 66329-3*** | — | — | — | | | 66330-3*** | — | | |
| | | | Silver* | 66255-7 | 66252-6 | 66255-8 | 66252-7 | | | 66261-4 | 66258-4 | | |
| | | | | 66256-6** | — | — | — | | | 66262-4** | — | | |
| 10-8 | 5-8 | .190-.270 [4.83-5.59] | Set Gold/Nickel‡ | 66253-2 | 66251-2 | 66253-6 | 66251-6 | 565584-1 | 387021-2 | 66259-2 | 66257-2 | 90384-1 | 90145-1 |
| | | | | 66254-2** | — | — | — | | | 66260-2** | — | | |
| | | | | 66326-2*** | — | — | — | | | 66327-2*** | — | | |
| | | | Set Gold/Nickel‡ | 66253-3 | 66251-3 | 66253-7 | 66251-7 | | | 66259-3 | 66257-3 | | |
| | | | | 66254-3** | — | — | — | | | 66260-3** | — | | |
| | | | | 66326-3*** | — | — | — | | | 66327-3*** | — | | |
| | | | Silver* | 66253-4 | 66251-4 | 66253-8 | 66251-8 | | | 66259-4 | 66257-4 | | |
| | | | | 66254-4** | — | — | — | | | 66260-4** | — | | |

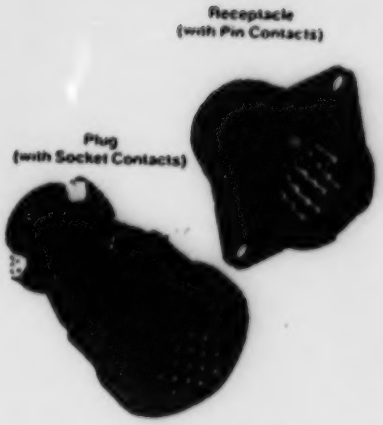
*Wire strip length — .281 [7.14] (all wire sizes)
‡Gold flash over .000050 [0.00127] nickel on entire contact, with additional .000030 [0.00076] gold on electrical engagement area.
‡Gold flash over .000050 [0.00127] nickel on entire contact, with additional .000015 [0.00038] gold on electrical engagement area.
* .000200 [0.00508] silver with lubricant added — recommended for high current/vibration applications where fretting corrosion is a problem.
**Grounding contact
***High voltage contact
†Die Insert No. 91015-1 is for crimping 14-12 AWG [2-3 mm²] wire, and Die Insert No. 91045-2 is for crimping 16 AWG [1.25-1.4 mm²] wire.
Extraction Tool No. 91019-3 (Economy version No. 91134-1 is for maintenance only).
Note: These contacts can be used in Series 3 connectors, as well as Series 4 connectors with power contact cavities.

# Part Number Guide
# (for CPC Connectors)

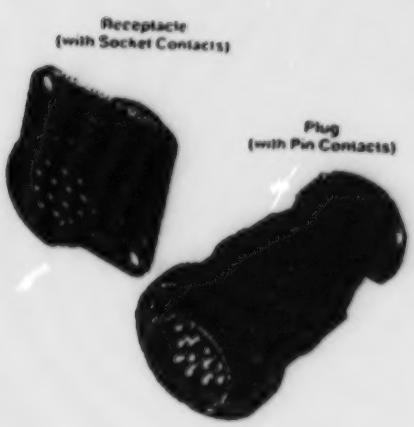
**Dimensioning:**
All dimensions in inches and millimeters
Values in brackets are metric equivalents

The Part Number Guides presented on this page and on page 125 list the part numbers of all available CPC connector configurations, except the special versions which are contained on pages 151 thru 154. Page number references provided in the Guides indicate the location of detailed engineering information. Also, the connector class, indicated in parentheses, specifies (A) as unsealed and (F) as sealed.

**Material:**
UL recognized, 94V-1 rated, heat stabilized, fire resistant, self extinguishing thermoplastic
Color: black




Standard Sex Connectors




Reverse Sex Connectors

| Series (Class) | Arrangement No. | Sex* | Receptacles: Square Flange | Receptacles: Free Hanging | Plugs: Standard Lettering | Plugs: Reverse Lettering | Feed-Thru Receptacles: With Jam Nut | Feed-Thru Receptacles: Without Jam Nut |
|---|---|---|---|---|---|---|---|---|
| 1(A) (Dg. 128, 129) | 11-4 | Std | 206061-1 | 206153-1 | 206060-1 | — | — | — |
| | | Rev | 206430-1 | 206430-2 | 206429-1 | — | — | — |
| | 13-9 | Std | 206705-1 | 206705-2 | 206708-1 | — | — | — |
| | 17-14 | Rev | 206043-1 | 206043-3 | 206044-1 | — | — | — |
| | 17-16 | Std | 206036-1 | 206036-3 | 206037-1 | — | — | — |
| | 23-24 | Std | 205838-1 | 205838-2 | 206837-1 | — | — | — |
| | 23-37 | Std | 206151-1 | 206151-2 | 206150-1 | — | — | — |
| | | Rev | 206306-1 | 206306-2 | 206305-1 | — | — | — |
| 1(F) (Dg. 128, 129) | 11-4 | Std | — | — | 206517-1 | 206516-1 | — | 206518-2* 206518-1* |
| | 17-16 | Std | — | — | 206553-1 | 206554-1 | — | 206552-1* 206552-2* |
| | 23-37 | Std | — | — | 206369-1 | 206370-1 | 207364-1* 207364-2* | 207364-1* 207364-2* |
| 2(A) (Dg. 134, 135) | 11-6 | Std | 205841-1 | 205841-2 | 206438-1 | — | — | — |
| | | Rev | 206433-1 | 206433-2 | 206434-1 | — | — | — |
| | 11-9 | Std | 206486-1 | 206486-2 | 206485-1 | — | — | — |
| | 17-26 | Std | 205840-1 | 206152-1 | 205839-3 | — | — | — |
| | | Rev | 206038-1 | 206038-2 | 206039-1 | — | — | — |
| | 23-57 | Rev | 206438-1 | 206438-2 | 206437-1 | — | — | — |
| | 23-63 | Std | 205843-1 | 205843-2 | 205842-1 | — | — | — |
| 2(F) (Dg. 134, 135) | 11-6 | Std | — | — | 206459-1 | 206460-1 | — | 206458-1* 206458-2* |
| | 17-26 | Std | — | — | 206125-1 | 206126-1 | — | 206127-1* |
| | 23-63 | Std | — | — | 206377-1 | 206378-1 | 207363-1* 207363-2* | 207363-1* 207363-2* |
| 3(A) (Dg. 139) | 17-3 | Std | 206036-2 | 206707-1 | 206037-2 | — | — | — |
| | | Rev | 206425-1 | 206425-2 | 206426-1 | — | — | — |
| | 23-7 | Std | 206137-1 | 206137-2 | 206136-1 | — | — | — |
| | | Rev | 206227-1 | 206227-2 | 206226-1 | — | — | — |
| 4(A) (Dg. 142) | 23-18M | Std | 207486-1 | 207486-2 | 207485-1 | — | — | — |
| | 23-22M | Std | 206613-1 | 206613-3 | 206612-1 | — | — | — |

Standard sex: pin contacts in receptacle housings, socket contacts in plug housings
Reverse sex: socket contacts in receptacle housings, pin contacts in plug housings
*Receptacle with gold over nickel plated pin contacts
†Receptacle with tin plated pin contacts
‡Jam nut style receptacle with gold over nickel plated pin contacts
§Jam nut style receptacle with tin plated pin contacts

Notes: 1. A complete feed-thru assembly requires: One plug with reversely marked cavity identification. One receptacle with reverse marked cavity identification.
2. All connectors can be supplied with [illegible] inserts installed in the mounting holes. See page 151.
3. All receptacles can be supplied with pc [illegible] solder bonded into the connector housing. See page 147.
4. Replacement coupling rings for plugs are available in the following style codes: 11—206069-1, 13—206707-1, 17—206038-1, 23—206251-1



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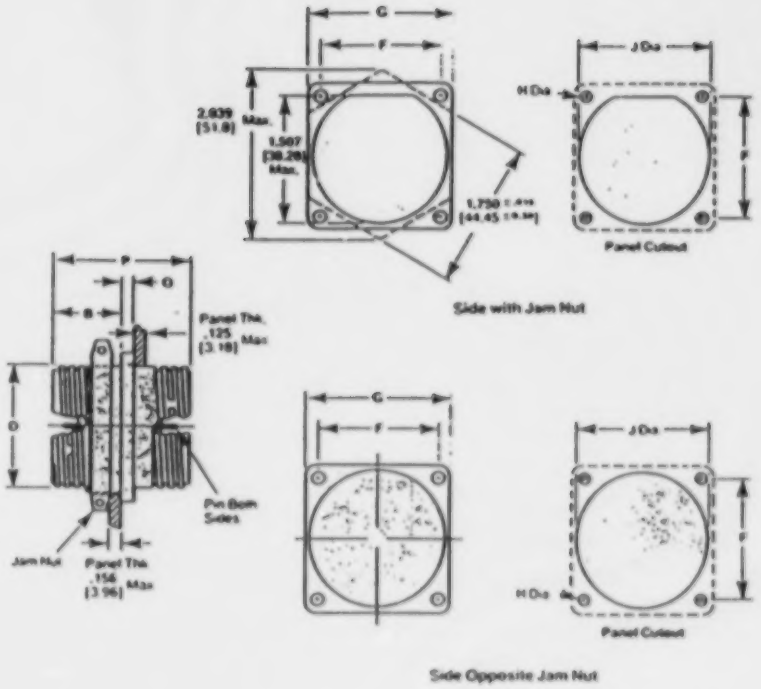
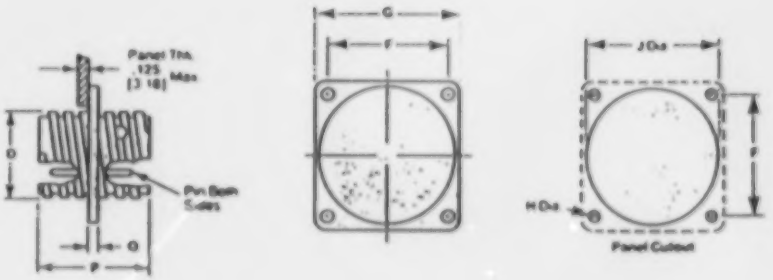
SKETCH NO. A-1098
SHEET E3

Dimensioning:
All dimensions in inches and millimeters.
Values in brackets are metric equivalents.

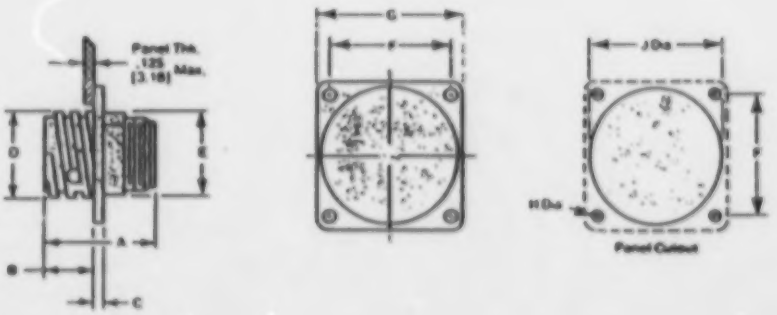
## Feed-Thru Receptacle, Jam Nut Style (Class F)




## Feed-Thru Receptacle (Class F)




## Square Flange Receptacle (Class A)




Note: Specific values of lettered dimensions are presented on page 138.



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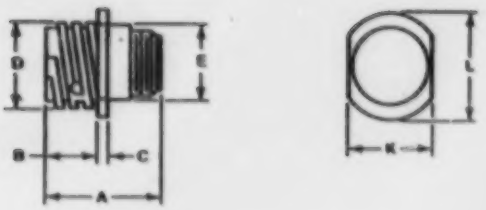
SKETCH NO. A-1098
SHEET E4

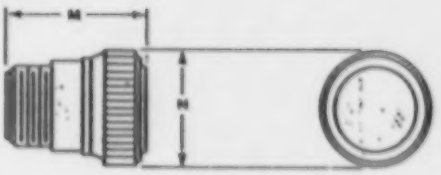
# Series 1
# Component Dimensions

**Dimensioning:**
All dimensions in inches and millimeters.
Values in brackets are metric equivalents.
Chart contains dimensions in inches over millimeters.

## Free Hanging Receptacle (Class A)




## Plug (Class A and F)




| Arrangement No. | Sex | Dimensions | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A Max. | B ±.015 ±0.38 | C ±.010 ±0.25 | D ±.010 ±0.25 | E Max. | F ±.010 ±0.25 | G ±.025 ±0.64 | H +.007 −0.38 +0.18 | J | K Max. | L Max. | M Max. | N Max. | P Max. | Q ±.010 ±0.25 |
| 11-4 | Rec. | 1.070 27.18 | .439 10.67 | .094 2.39 | .687 17.45 | .748 18.8 | .844 21.44 | 1.125 28.58 | .135 3.18 | .840 21.33 | .817 20.75 | .835 23.75 | 1.365 34.68 | .943 23.93 | — | — |
| | Std. | 1.350 34.29 | | | | | | | | | | | 1.080 27.43 | | 1.300 30.71 | 0.94 2.39 |
| 13-9 | Std. | 1.350 34.29 | .439 10.67 | .094 2.39 | .812 20.62 | .875 22.23 | .969 24.61 | 1.281 31.01 | .135 3.18 | .979 24.87 | .874 22.2 | 1.073 27.23 | 1.080 27.43 | 1.079 27.18 | — | — |
| 17-14 | Rec. | 1.070 27.18 | .439 10.67 | .094 2.39 | 1.050 26.67 | 1.110 28.2 | 1.133 28.58 | 1.435 36.45 | .150 3.81 | 1.310 30.73 | 1.161 29.49 | 1.310 33.27 | 1.365 34.68 | 1.315 33.4 | — | — |
| 17-16 | Std. | 1.350 34.29 | | | | | | | | | | | 1.080 27.43 | | 1.300 30.71 | 0.94 2.39 |
| 23-24* | Std. | 1.350 34.29 | .539 13.71 | .156 3.96 | 1.438 36.53 | 1.510 38.36 | 1.438 36.53 | 1.750 44.45 | .150 3.81 | 1.610 40.89 | 1.385 35.23 | 1.733 44.02 | 1.080 27.43 | 1.743 44.27 | — | — |
| 23-37** | Std. | — | .539 20.98 | — | 1.438 36.53 | — | 1.438 36.53 | 1.750 44.45 | .150 3.81 | 1.610 40.89 | — | — | — | — | 1.660 42.37 | .156 3.96 |
| 23-37 | Rec. | 1.070 27.18 | .539 13.71 | .156 3.96 | 1.438 36.53 | 1.510 38.36 | 1.438 36.53 | 1.750 44.45 | .150 3.81 | 1.610 40.89 | 1.385 35.23 | 1.733 44.02 | 1.365 34.68 | 1.743 44.27 | — | — |
| | Std. | 1.350 34.29 | | | | | | | | | | | 1.080 27.43 | | 1.660 42.37 | .156 3.96 |

*Plug and receptacle accept Type II, III-, VI, X, subminiature CLINXICON or filter optic contacts. Contacts for insulation diameters up to .120 [3.81].
**Jam nut style receptacle only, with or without jam nut.

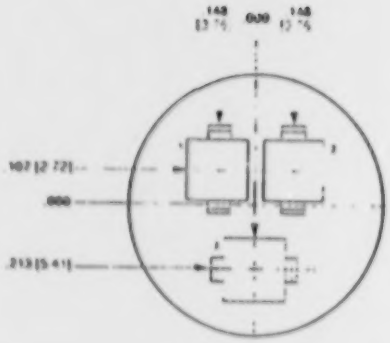
Notes: 1. Mated dimensions of various combinations of connector configurations and accessories are provided on pages 130 & 131.
2. For specific part nos. of Series 1 connectors, refer to Part Number Guide, page 124.



SKETCH NO. A-109
SHEET E5

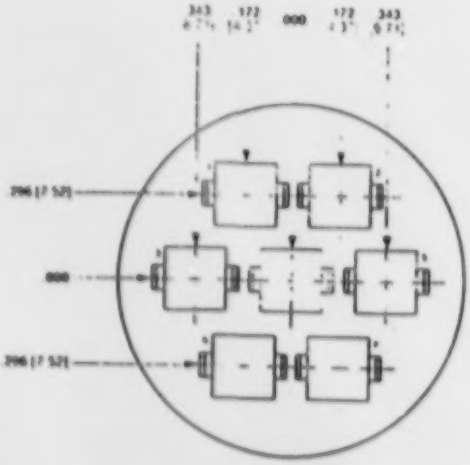
Dimensioning:
All dimensions in inches and millimeters.
Values in brackets are metric equivalents.

Shell Size 17




Arrangement 17-3
Max. Wire Ins. Dia. = .220 [5.59]

Shell Size 23




Arrangement 23-7
Max. Wire Ins. Dia. = .220 [5.59]

Note: Contact arrangements shown
are of pin mating face plug or
receptacles. Socket mating faces
are mirror image.



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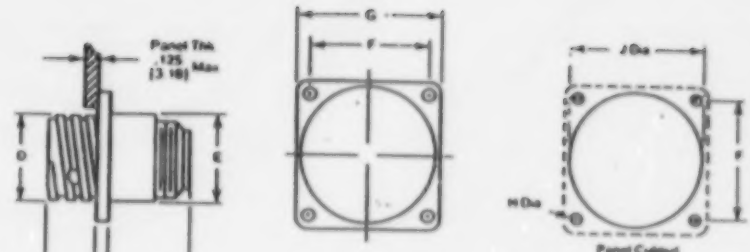
SKETCH NO. A-1098
SHEET E6

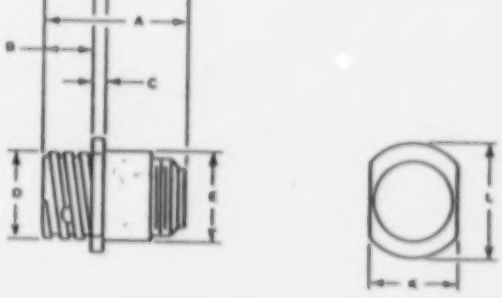
# Series 3
## Component Dimensions

Dimensioning:
All dimensions in inches and millimeters.
Values in brackets are metric equivalents.
Chart contains dimensions in inches over millimeters.

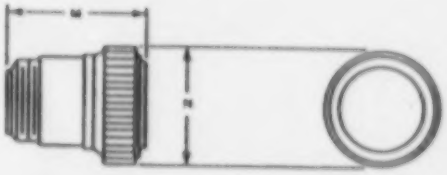
### Square Flange Receptacle (Class A)




### Free Hanging Receptacle (Class A)




### Plug (Class A)




| Arrangement No. | A Max. | B .015 [0.38] | C* ± .010 [0.25] | D ± .010 [0.25] | E Max. | F ± .010 [0.25] | G ± .025 [0.64] | H ± .007 [0.18] | J | K Max. | L Max. | M Max. | N Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17-3 | 1.635 [41.53] | .420 [10.67] | .094 [2.39] | 1.059 [26.67] | 1.110 [28.2] | 1.135 [28.58] | 1.405 [35.45] | .119 [3.01] | 1.219 [30.73] | 1.161 [29.49] | 1.319 [33.27] | 1.645 [41.78] | 1.310 [33.4] |
| 23-7 | 1.635 [41.53] | .520 [13.21] | .156 [3.96] | 1.436 [36.53] | 1.510 [38.35] | 1.436 [36.53] | 1.780 [44.45] | .119 [3.01] | 1.619 [40.89] | 1.565 [39.73] | 1.733 [44.02] | 1.645 [41.78] | 1.743 [44.27] |

Notes: 1. All dimensions apply to both standard and reverse sex.
2. For specific part nos. of Series 3 connectors, refer to Part Number Guide, page 104.



SKETCH NO. A-1098
SHEET E7

On Receptacles:
All dimensions in inches and millimeters. Values in brackets are metric equivalents.
Charts contain dimensions in inches over millimeters.

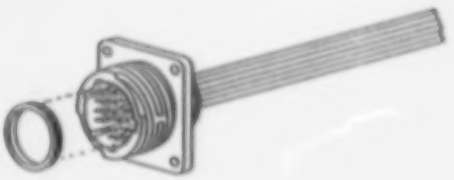
## Peripheral Seals (for Receptacles only)

Peripheral seals are recommended for use in sealing/splash-proof applications, or where connectors will be subjected to vibration.

**Material:**
White Neoprene

| Shell Size | Dimensions A | Dimensions B | Peripheral Seal Part Number | Std. Size Receptacle with Peripheral Seal Bonded In: Contact Arrangement | Std. Size Receptacle with Peripheral Seal Bonded In: Part Number |
|---|---|---|---|---|---|
| 11 | .524 [13.31] | .041 [1.04] | 206403-1 | — | — |
| 13 | .650 [16.51] | .050 [1.27] | 206403-4 | — | — |
| 17 | .875 [22.23] | .050 [1.27] | 206403-2 | 17-16 | 206836-4 |
| 23 | 1.230 [31.24] | .050 [1.27] | 206403-3 | 23-7 | 206137-3 |
| | | | | 23-22M | 206513-2 |
| | | | | 23-24 | 206838-3 |
| | | | | 23-37 | 205151-3 |

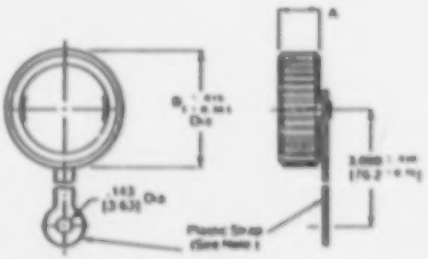
Notes: 1. Peripheral seals can be bonded into receptacles of other sizes. Consult AMP Incorporated for details.
2. For detailed performance data on peripheral seals, refer to AMP Product Specification No. 108-1800.



## Sealing Caps (for Receptacles only)

Sealing caps are used to protect exposed contacts of unmated receptacles.

**Material:**
Cap — Black Thermoplastic, Heat Stabilized, Fire Resistant, Self-Extinguishing, 94V-1 Rated
Sealing Gasket — Black Neoprene
Bead Chain — Nickel Plated Steel
Bead Chain Coupling — Nickel Plated Brass




| Shell Size | Series | Dimensions A | Dimensions B | Part Number: Plastic Strap | Part Number: Metal Bead Chain |
|---|---|---|---|---|---|
| 11 | 1 & 3 | .360 [9.14] | .927 [23.55] | 206703-1 | 206650-1 |
| 17 | 1 & 3 | .360 [9.14] | 1.305 [33.15] | 207445-1 | 206652-1 |
| 23 | 1 & 3 | .660 [16.76] | 1.728 [43.89] | 207446-1* | 206660-1* |
| | 2 | | | 207446-2** | 206660-2** |

*These sealing caps are used with Series 1 and Series 3 receptacles.
**These sealing caps are used with Series 2 receptacles.

Note: Sealing caps are supplied with either a plastic strap or metal bead chain. See chart above.

CEMA/NEMA Type 12

# Oil and Dust Tight Enclosures

**1418 Series**
**Single Door**
**Indoor Use**
**Panel Incl.**

### Application:

- construction meets industrial environments.
- for special motor starter assemblies and complex machine tool controls.
- to protect sophisticated industrial electronic control systems.
- enclosure for electrical, pneumatic or hydraulic control and instrumentation systems.

### Standards:

- built to CEMA/NEMA TYPE 12 specifications (Industrial Use).
- constructed to NEMA TYPE 13 specifications (Oil and Dust Tight).
- CSA certified, LR 21001, for use with industrial control equipment in ordinary locations. Constructed to requirements of CSA enclosure 5.
- CSA certified, LL21312, for use as electric box Enclosure 5.
- Those models marked Ⓤ are UL Listed.

### Construction:

- continuously welded box formed from 14 gauge steel.
- back has 4, 6 or 8 .375-#16 collar studs for mounting equipment panel.
- all enclosures include formed 12 gauge inner panel (those marked • are flat). White enamel.
- continuous piano hinge on single door with stainless steel door clamping hardware on alternate side.
- oil resistant neoprene gasket permanently secured.
- padlock hasp and removable data pocket on inside of door.
- box and door phosphatized then finished in ANSI/ASA 61 gray, baked, recoatable enamel outside
- white baked enamel interiors.

| Part No. | A | B | C | Panel Size | Shipping Wt. |
|---|---|---|---|---|---|
| 1418 AG• Ⓤ | 12 | 24 | 6 | 9 x 21 | 36 |
| 1418 BG• Ⓤ | 16 | 12 | 6 | 13 x 9 | 28 |
| 1418 GG• Ⓤ | 16 | 16 | 6 | 13 x 13 | 32 |
| 1418 CH6• Ⓤ | 16 | 20 | 6 | 13 x 17 | 36 |
| 1418 C44 Ⓤ | 20 | 12 | 6 | 17 x 9 | 36 |
| 1418 CG• Ⓤ | 20 | 16 | 6 | 17 x 13 | 38 |
| 1418 DG• Ⓤ | 20 | 20 | 6 | 17 x 17 | 48 |
| 1418 EH6 Ⓤ | 20 | 24 | 6 | 21 x 17 | 56 |
| 1418 AH6• Ⓤ | 24 | 12 | 6 | 21 x 9 | 36 |
| 1418 HG Ⓤ | 24 | 16 | 6 | 21 x 13 | 48 |
| 1418 EG Ⓤ | 24 | 20 | 6 | 21 x 17 | 56 |
| 1418 JG Ⓤ | 24 | 24 | 6 | 21 x 21 | 62 |
| 1418 FG6 Ⓤ | 30 | 16 | 6 | 27 x 13 | 68 |
| 1418 FG Ⓤ | 30 | 20 | 6 | 27 x 17 | 68 |
| 1418 GG Ⓤ | 30 | 24 | 6 | 27 x 21 | 72 |
| 1418 LG Ⓤ | 36 | 24 | 6 | 33 x 21 | 91 |
| 1418 MG Ⓤ | 36 | 30 | 6 | 33 x 27 | |
| 1418 AG• Ⓤ | 12 | 24 | 8 | 9 x 21 | 42 |
| 1418 BG• Ⓤ | 16 | 12 | 8 | 13 x 9 | 38 |
| 1418 GG• Ⓤ | 16 | 16 | 8 | 13 x 13 | 62 |
| 1418 CH6• Ⓤ | 16 | 20 | 8 | 13 x 17 | 45 |
| 1418 C44 Ⓤ | 20 | 12 | 8 | 17 x 9 | |
| 1418 CG Ⓤ | 20 | 16 | 8 | 17 x 13 | |
| 1418 DG• Ⓤ | 20 | 20 | 8 | 17 x 17 | 53 |
| 1418 EH6 Ⓤ | 20 | 24 | 8 | 17 x 21 | 61 |
| 1418 AH6 Ⓤ | 24 | 12 | 8 | 21 x 9 | 48 |
| 1418 HG Ⓤ | 24 | 16 | 8 | 21 x 13 | 56 |
| 1418 EG Ⓤ | 24 | 20 | 8 | 21 x 17 | 64 |
| 1418 JG Ⓤ | 24 | 24 | 8 | 21 x 21 | 70 |
| 1418 KH6 Ⓤ | 24 | 30 | 8 | 21 x 27 | 80 |
| 1418 KAG Ⓤ | 30 | 12 | 8 | 27 x 9 | 56 |
| 1418 KGG Ⓤ | 30 | 16 | 8 | 27 x 13 | 64 |
| 1418 FG Ⓤ | 30 | 20 | 8 | 27 x 17 | 72 |
| 1418 KG Ⓤ | 30 | 24 | 8 | 27 x 21 | 80 |
| 1418 KKG Ⓤ | 30 | 30 | 8 | 27 x 27 | 88 |
| 1418 MKG Ⓤ | 36 | 36 | 8 | 33 x 33 | 106 |
| 1418 LG Ⓤ | 36 | 24 | 8 | 33 x 21 | 106 |
| 1418 MG Ⓤ | 36 | 30 | 8 | 33 x 27 | 106 |
| 1418 LLG Ⓤ | 36 | 36 | 8 | 33 x 33 | 142 |
| 1418 KG Ⓤ | 42 | 24 | 8 | 39 x 21 | 130 |
| 1418 GG Ⓤ | 42 | 30 | 8 | 39 x 27 | 130 |
| 1418 PG Ⓤ | 42 | 36 | 8 | 39 x 33 | 178 |
| 1418 QG Ⓤ | 48 | 24 | 8 | 45 x 21 | 136 |
| 1418 RG Ⓤ | 48 | 30 | 8 | 45 x 27 | 170 |
| 1418 SG Ⓤ | 48 | 36 | 8 | 45 x 33 | 201 |
| 1418 TG Ⓤ | 60 | 30 | 8 | 57 x 33 | 252 |
| 1418 B16• Ⓤ | 16 | 12 | 16 | 13 x 9 | 34 |
| 1418 C16• Ⓤ | 20 | 16 | 16 | 17 x 13 | 48 |
| 1418 D16• Ⓤ | 20 | 20 | 16 | 17 x 17 | 54 |

Ⓤ UL listed • Flat panel

| Part No. | A | B | C | Panel Size | Shipping Wt. |
|---|---|---|---|---|---|
| 1418 AG10• Ⓤ | 24 | 12 | 10 | 21 x 9 | 44 |
| 1418 C10 Ⓤ | 24 | 20 | 10 | 21 x 17 | 64 |
| 1418 J10 Ⓤ | 24 | 24 | 10 | 21 x 21 | 74 |
| 1418 F10 Ⓤ | 30 | 20 | 10 | 27 x 17 | 77 |
| 1418 K10 Ⓤ | 30 | 24 | 10 | 27 x 21 | 86 |
| 1418 L10 Ⓤ | 36 | 24 | 10 | 33 x 21 | 105 |
| 1418 M10 Ⓤ | 36 | 30 | 10 | 33 x 27 | 124 |
| 1418 O10 Ⓤ | 42 | 30 | 10 | 39 x 27 | 132 |
| 1418 P10 Ⓤ | 42 | 36 | 10 | 39 x 33 | 166 |
| 1418 R10 Ⓤ | 48 | 30 | 10 | 45 x 27 | 166 |
| 1418 S10 Ⓤ | 48 | 36 | 10 | 45 x 33 | 210 |
| 1418 T10 Ⓤ | 60 | 30 | 10 | 57 x 33 | 252 |
| 1418 C12• Ⓤ | 20 | 16 | 12 | 17 x 13 | 56 |
| 1418 E12 Ⓤ | 24 | 20 | 12 | 21 x 17 | 80 |
| 1418 J12 Ⓤ | 24 | 24 | 12 | 21 x 21 | 88 |
| 1418 K12 Ⓤ | 30 | 24 | 12 | 27 x 21 | 93 |
| 1418 KK12 Ⓤ | 30 | 30 | 12 | 27 x 27 | 118 |
| 1418 L12 Ⓤ | 36 | 24 | 12 | 33 x 21 | 118 |
| 1418 M12 Ⓤ | 36 | 30 | 12 | 33 x 27 | 130 |
| 1418 LL12 Ⓤ | 36 | 36 | 12 | 33 x 33 | 157 |
| 1418 O12 Ⓤ | 42 | 30 | 12 | 39 x 27 | |
| 1418 P12 Ⓤ | 42 | 36 | 12 | 39 x 33 | 192 |
| 1418 S12 Ⓤ | 48 | 36 | 12 | 45 x 33 | 218 |
| 1418 T12 Ⓤ | 60 | 30 | 12 | 57 x 33 | 261 |
| 1418 U12 Ⓤ | 72 | 30 | 12 | 69 x 27 | |
| 1418 E16 Ⓤ | 24 | 20 | 16 | 21 x 17 | |
| 1418 J16 Ⓤ | 24 | 24 | 16 | 21 x 21 | |
| 1418 K16 Ⓤ | 30 | 24 | 16 | 27 x 21 | 94 |
| 1418 M16 Ⓤ | 36 | 30 | 16 | 33 x 27 | 165 |
| 1418 P16 Ⓤ | 42 | 36 | 16 | 39 x 33 | 224 |
| 1418 S16 Ⓤ | 48 | 36 | 16 | 45 x 33 | 238 |
| 1418 T16 Ⓤ | 60 | 30 | 16 | 57 x 33 | 261 |
| 1418 U16 Ⓤ | 72 | 30 | 16 | 69 x 27 | |
| 1418 K20 Ⓤ | 30 | 24 | 20 | 27 x 21 | 115 |
| 1418 M20 Ⓤ | 36 | 30 | 20 | 33 x 27 | |
| 1418 S20 Ⓤ | 48 | 36 | 20 | 45 x 33 | 294 |
| 1418 T20 Ⓤ | 60 | 30 | 20 | 57 x 33 | |
| 1418 U20 Ⓤ | 72 | 30 | 20 | 69 x 27 | |
| 1418 K24 Ⓤ | 30 | 24 | 24 | 27 x 21 | |
| 1418 U24 Ⓤ | 72 | 30 | 24 | 69 x 27 | |



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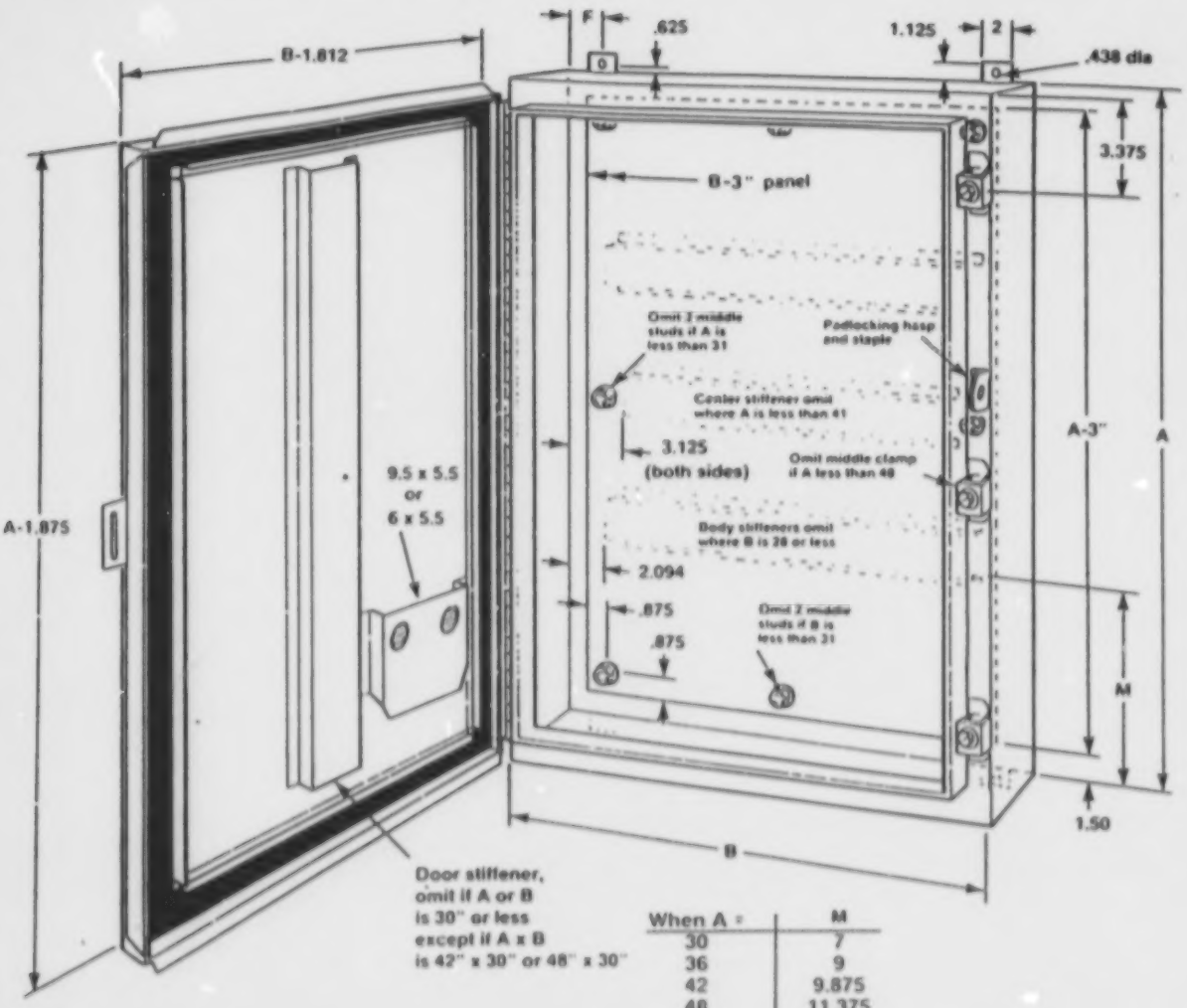
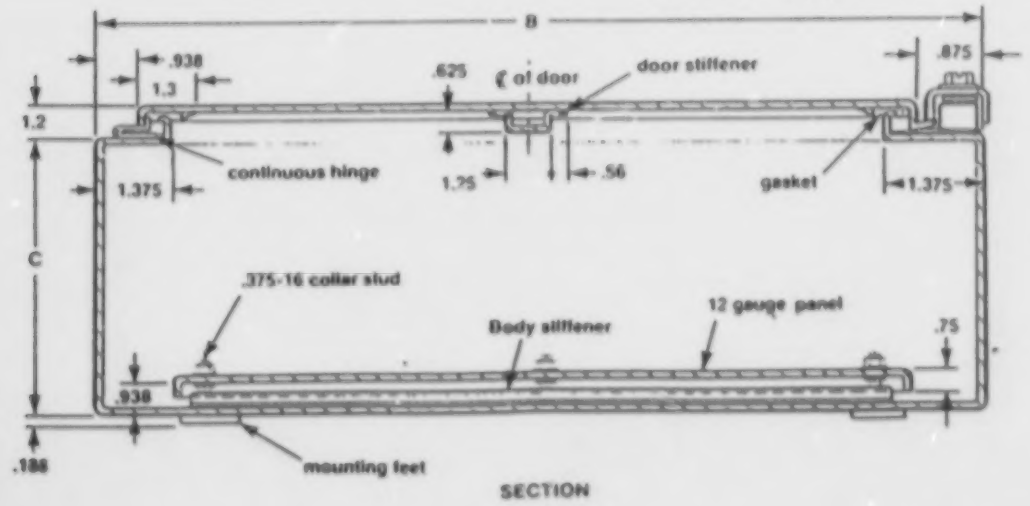
SKETCH NO. A-1098 SHEET F1

Note: F = 3" where B = 16" or more
F = 1.25" where B is less than 16"

# Oil and Dust Tight Enclosures


F
.625
1.125
2
.438 dia
B-1.812
B-3" panel
3.375
A-3"
A
A-1.875
Omit 2 middle studs if A is less than 31
Padlocking hasp and staple
Center stiffener omit where A is less than 41
3.125 (both sides)
Omit middle clamp if A less than 48
9.5 x 5.5 or 6 x 5.5
Body stiffeners omit where B is 20 or less
2.094
.875
.875
Omit 2 middle studs if B is less than 31
M
1.50
B
Door stiffener, omit if A or B is 30" or less except if A x B is 42" x 30" or 48" x 30"

| When A = | M |
|---|---|
| 30 | 7 |
| 36 | 9 |
| 42 | 9.875 |
| 48 | 11.375 |
| 60 | 14.375 |
| 72 | 17.375 |




SECTION

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# APPENDIX F

# SYSTEM DOCUMENTATION LIST

# APPENDIX F

## ICE HAZARD DETECTION SONAR SYSTEM DOCUMENTATION LIST

| DOCUMENT | DESCRIPTION | NOTE |
|---|---|---|
| **ICE HAZARD SONAR B-1206** | | |
| PL B-1206 | Ice Hazard Sonar | |
| C-1206 | Ice Hazard Sonar, Block Diagram | 1 APP G |
| B-729 | Ice Hazard Detection Sonar Operations Area Equipment Installation | 1 APP G |
| B-770 | Sonar Compartment | 1 APP G |
| CTL 1064 | Requirements for a Ruggedized Transducer Subsystem for Ice Hazard Detection Sonar | 1 APP B |
| CTL 1069 | Statement of Work, Retraction Mechanism Subsystem for Ice Hazard Detection Sonar | 1 APP D |
| CTL 1075 | System Design Specification for a Ruggedized Transducer Subsystem for Ice Hazard Detection Sonar | 1 APP C |
| **CDS-40A SONAR (MODIFIED & CALIBRATED) B-1203** | | |
| PL B-1203 | CDS-40A Sonar (Modified & Calibrated) | |
| **CDS-40 CONTROL/INDICATOR (P/N 12682-2 MODIFIED) B-1204** | | |
| PL B-1204 | CDS-40A Control/Indicator (P/N 12682-2 Modified) | |
| 12926 | VCR Interface Option | |
| **AUDIO & RECORDER INTERFACE UNIT P/N 12918** | | |
| 12918 | Audio & Recorder Interface Unit | |
| **TRANSMITTER/RECEIVER (P/N 12452-2 MODIFIED) B-1205** | | |
| B-1205 | Transmitter/Receiver (P/N 12452-2 Modified) | |

| DOCUMENT | DESCRIPTION | NOTE |
|---|---|---|

ICE FLUX MONITOR B-1199

| | |
|---|---|
| PL B-1199 | Ice Flux Monitor |

FFC-2000 MAIN UNIT (MODIFIED) B-1207

| | |
|---|---|
| PL B-1207 | FFC-2000 Main Unit (Modified) |
| B-1067 | A10 Power Supply Board (Modified) Schematic |
| B-799 | Display Unit Wiring Diagram (Modified) |
| B-828 | A1 CPU Board (Modified) Schematic |
| B-829 | A5 Main Control Panel Board (Modified) Schematic |
| B-950 | Main Control Panel |

ICE FLUX MONITOR SUBCHASSIS B-1012

| | |
|---|---|
| PL B-1012 | Ice Flux Monitor Subchassis |
| A-860 | Controller I Assembly |
| A-867 | Formatter I Assembly |
| PL B-981 | Front Panel Assembly |
| B-981 | Front Panel Assembly |
| B-982 | Front Panel, Machined |
| B-984 | Protective Panel, Machined |
| C-1002 | Optical Cable Gland |
| D-983 | Ice Flux Monitor Wiring Diagram |
| D-985 | Chassis, Reworked |

OPERATIONS AREA CABLES B-1078

| | |
|---|---|
| B-1078 | Operations Area Cables |

| DOCUMENT | DESCRIPTION | NOTE |
|---|---|---|

PROXIMITY TRANS. UNIT B-996

| | |
|---|---|
| PL B-996 | Proximity Transceiver Unit |
| A-1010 | Transformer |
| A-1011 | Standoff |
| A-1061 | Plate, Power Supply |
| D-997 | Case, Transceiver |
| D-998 | Chassis, Transceiver |
| D-999 | Bracket, Left |
| D-1004 | Bracket, Top |
| D-1005 | Bracket, Right |
| E-1006 | Transceiver Unit Assembly |
| R-1077 | Transceiver Unit Wiring Diagram |
| 11280 | Caution Plate |
| 11822-2 | Name Plate |

FORWARD CHANNEL RECEIVER ASSEMBLY A-809

| | |
|---|---|
| A-809 | Forward Channel Receiver Assembly |
| A-787 | Inductor, IF Filter |
| A-788 | Inductor, IF Filter |
| A-791 | Transformer, RX Input |
| A-793 | Transformer, TRF |

PULSE DETECTION ASSEMBLY B-1020

| | |
|---|---|
| B-1020 | Pulse Detection Assembly |

NOTE

HOIST INTERFACE ASSEMBLY B-1021

| | |
|---|---|
| B-1021 | Hoist Interface Assembly |

CONTROLLER 2 ASSEMBLY A-861

| | |
|---|---|
| A-861 | Controller 2 Assembly |

| DOCUMENT | DESCRIPTION | NOTE |
|---|---|---|
| **DOWNWARD CHANNEL RECEIVER & TX DRIVE ASSEMBLY A-812** | | |
| A-812 | Downward Channel Receiver & TX Drive Assembly | |
| A-786 | Inductor, TX Drive | |
| A-790 | Transformer, RX Input | |
| A-792 | Transformer, TRF | |
| **RECEIVE PULSE PROCESSOR ASSEMBLY A-1019** | | |
| A-1019 | Receive Pulse Processor Assembly | |
| **FORMATTER 2 ASSEMBLY A-A868** | | |
| PL A-868 | Formatter 2 Assembly | |
| **FORWARD CHANNEL TRANSMITTER ASSEMBLY B-811** | | |
| B-811 | Forward Channel Transmitter Assembly | |
| A-794 | Transformer, Isolation T1 | |
| A-796 | Transformer, TX Output T2 | |
| 12335-A | Printed Circuit Board | |
| **DOWNWARD CHANNEL TRANSMITTER ASSEMBLY B-813** | | |
| B-813 | Downward Channel Transmitter Assembly | |
| A-795 | Transformer, TX Output T2 | |
| **POWER SUPPLY ASSEMBLY B-1007** | | |
| PL B-1007 | Power Supply Assembly | |
| B-1007 | Power Supply Assembly | |
| **CONNECTOR BRACKET ASSEMBLY B-1000** | | |
| C-1002 | Optical Cable Gland | |
| B-1000 | Connector Bracket Assembly | |
| C-1003 | Bracket, Connector | |

| DOCUMENT | DESCRIPTION | NOTE |
|---|---|---|
| **TRANSCEIVER UNIT WIRING DIAGRAM R-1077** | | |
| R-1077 | Transceiver Unit Wiring Diagram | |
| **HULL UNIT B-734** | | |
| PL B-734 | Hull Unit | |
| PL B-804 | Extension Cable Assembly | |
| A-968 | Gasket | |
| A-1063 | Hull Unit Block Diagram | 1 APP G |
| C-1101 | Hull Unit Installation Diagram | |
| E-1127 | Ship's Modification (MV Arctic) | |
| **SEA CHEST ASSEMBLY B-967** | | |
| PL B-967 | Sea Chest Assembly | |
| A-993 | Protective Coating | |
| A-995 | Switch, Liquid Level | |
| A-1073 | Gasket | |
| **AIR SUPPLY SYSTEM B-969** | | |
| PL B-969 | Air Supply System | |
| **RETRACTION MECHANISM B-769** | | |
| PL B-769 | Retraction Mechanism | |
| A-968 | Gasket | |
| A-993 | Protective Coating | |
| D-859 | Tee Assembly, Reducing | |
| CD-2157-2 | Sonar Actuator Column | |
| CD-2157-5 | Arrangement of Sonar System Sea Chest | |
| CD-2157-6 | Retraction Mechanism Subsystem Calculation Report | |

| DOCUMENT | DESCRIPTION | NOTE |
|---|---|---|

TRANSDUCER SUPPORT ASSEMBLY B-970

| | |
|---|---|
| PL B-970 | Transducer Support Assembly |
| A-888 | Bushing |
| A-973 | Gasket, Housing |
| B-863 | Bushing, Lifting Shaft |
| C-866 | Housing Assembly |

TRANSDUCER SUBSYSTEM B-766

| | |
|---|---|
| PL B-766 | Transducer Subsystem |
| B-743 | Sleeve, Protective |
| B-745 | Proximity Transducer Assembly |
| B-766 | Transducer Assembly |
| C-885 | Sleeve, Guide, Lower |

TRANSDUCER, CDS-40 RUGGEDIZED B-742

| | |
|---|---|
| PL B-742 | Transducer CDS-40 Ruggedized |
| PL B-735 | Cable Assembly, Forward Array/Downward Element |
| PL B-803 | Cable Assembly, Transducer |
| A-429 | Leak Detector |
| B-735 | Cable Assembly, Forward Array/Downward Element |
| B-739 | Cover, Feed Thru |
| B-740 | Gasket Neoprene |
| B-756 | Gland Plate, Front |
| B-762 | Cover, Bottom |
| B-763 | Cover, Top |
| B-768 | Gland |
| B-803 | Cable Assembly, Transducer |
| B-806 | Housing Top |
| 12366 | Clamp, Cable Rework |

| DOCUMENT | DESCRIPTION | NOTE |
|---|---|---|

TRANSDUCER, PROXIMITY B-745

| | |
|---|---|
| PL B-745 | Proximity Transducer Assembly |
| A-424 | Washer, Corprene |
| A-425 | Cushion, Rear Mass |
| A-429 | Leak Detector |
| A-731 | Acoustic Window |
| A-738 | Spacer |
| A-748 | Gasket, Neoprene |
| A-753 | Element, Downward |
| A-754 | Cushion, Strip |
| A-755 | Cushion, Disk |
| A-757 | Ring, Window Retainer |
| A-758 | Rear Cover |
| A-759 | Gasket, Neoprene |
| B-746 | Frame, Proximity Transducer |
| B-747 | Housing |
| B-750 | Acoustic Window |
| B-751 | Retainer, Window |
| B-752 | Shield, PVC |
| PL B-749 | Proximity Transducer Element |
| A-760 | Bias Screw |
| A-767 | Element Assembly, Forward |
| B-724 | Rear Mass |
| B-727 | Front Mass |
| 11650-1 | Ceramic Ring |
| 13615 | Electrode |

COUPLING HOIST ASSEMBLY B-974

| | |
|---|---|
| PL B-974 | Coupling Hoist Assembly |
| A-889 | Slider |
| C-975 | Multiclamp, Cable Assembly |
| C-976 | Cover, Cable Support |
| D-892 | Coupling Hoist Slider Support |
| D-893 | Cable Support |

QUILL SHAFT ASSEMBLY B-972

| | |
|---|---|
| PL B-972 | Quill Shaft Assembly |
| A-884 | Shaft, Quill |
| B-886 | Flange, Transducer Support |

C-TECH LTD.

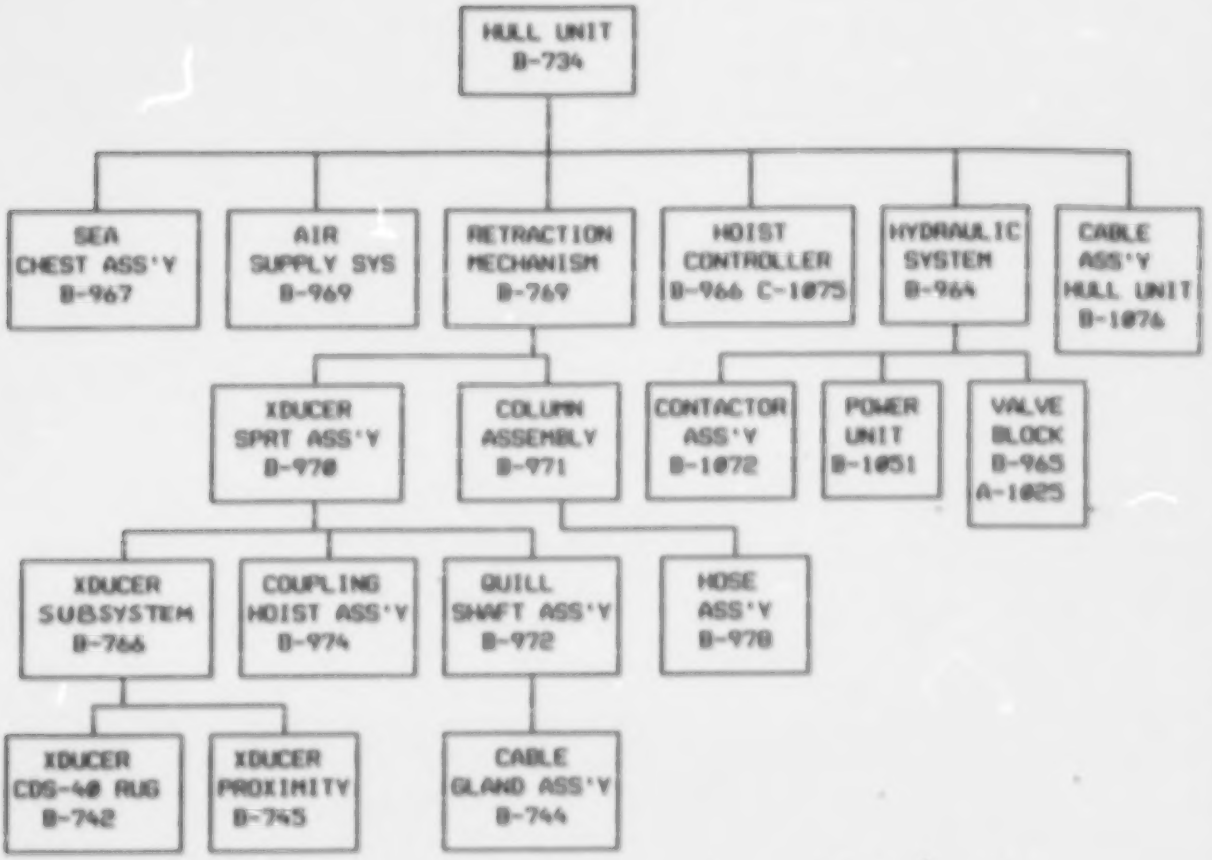
| DOCUMENT | DESCRIPTION | NOTE |
|---|---|---|
| **CABLE GLAND ASSEMBLY B-744** | | |
| PL B-744 | Cable Gland Assembly | |
| B-737 | Gland | |
| B-744 | Cable Gland Assembly | |
| B-764 | Gland Plate Assembly Bottom | |
| B-765 | Gland Plate Assembly Top | |
| 10850 | Gland, Bolt Reworked | |
| 10851 | Spacer | |
| **COLUMN ASSEMBLY B-971** | | |
| PL B-971 | Column Assembly | |
| A-883 | Rod, Connector | |
| A-890-1 | Pin, Pivot | |
| A-890-2 | Pin, Pivot | |
| A-891-1 | Bushing | |
| A-891-2 | Bushing | |
| A-1062 | Hydraulic Cushion Detail | |
| C-862 | Bracket, Supension | |
| C-1074 | Hydraulic Circuit | |
| CD 2157-1 | Hydraulic Actuator | |
| D-858 | Column, Lower | |
| D-882 | Column, Upper | |
| **HOSE ASSEMBLY B-978** | | |
| PL B-978 | Hose Assembly | |
| **HOIST CONTROLLER B-966** | | |
| PL B-966 | Hoist Controller | |
| A-1098 | Retraction Mechanism Controller for Ice Hazard Detection Sonar | 1 APP G |
| B-1075 | Hoist Controller Envelope & Interconnections | 1 APP G |

| DOCUMENT | DESCRIPTION | NOTE |
|---|---|---|
| **HYDRAULIC SYSTEM B-964** | | |
| PL B-964 | Hydraulic System | |
| A-1001 | Hydraulic Cylinder, Slugging | |
| A-1084 | Operation Of Hydraulic Circuit | |
| C-1074 | Hydraulic Circuit | |
| **CONTACTOR ASSEMBLY B-1072** | | |
| PL B-1072 | Contactor Assembly | |
| C-1096 | Schematic Power Control | |
| **POWER UNIT B-1051** | | |
| PL B-1051 | Power Unit | |
| B-1051 | Hydraulic System Power Unit | 1 APP G |
| **VALVE BLOCK B-965** | | |
| PL B-965 | Valve Block Assembly | |
| B-1025 | Valve Block Compartment/Installation | |
| **CABLE ASSEMBLY HULL UNIT B-1076** | | |
| PL B-1076 | Cable Assemblies, Hull Unit | |

NOTE: Copies of drawings denoted by a status code "1" are included in Appendices B, C, D, E and G of this report.
Copies of drawings without a status code are available to the design authority upon request.

# APPENDIX G

## SELECTED SYSTEM DOCUMENTATION




| ISSUE | DATE |
|---|---|
| 1 | 89-09-13 |
| 2 | 89-10-02 |

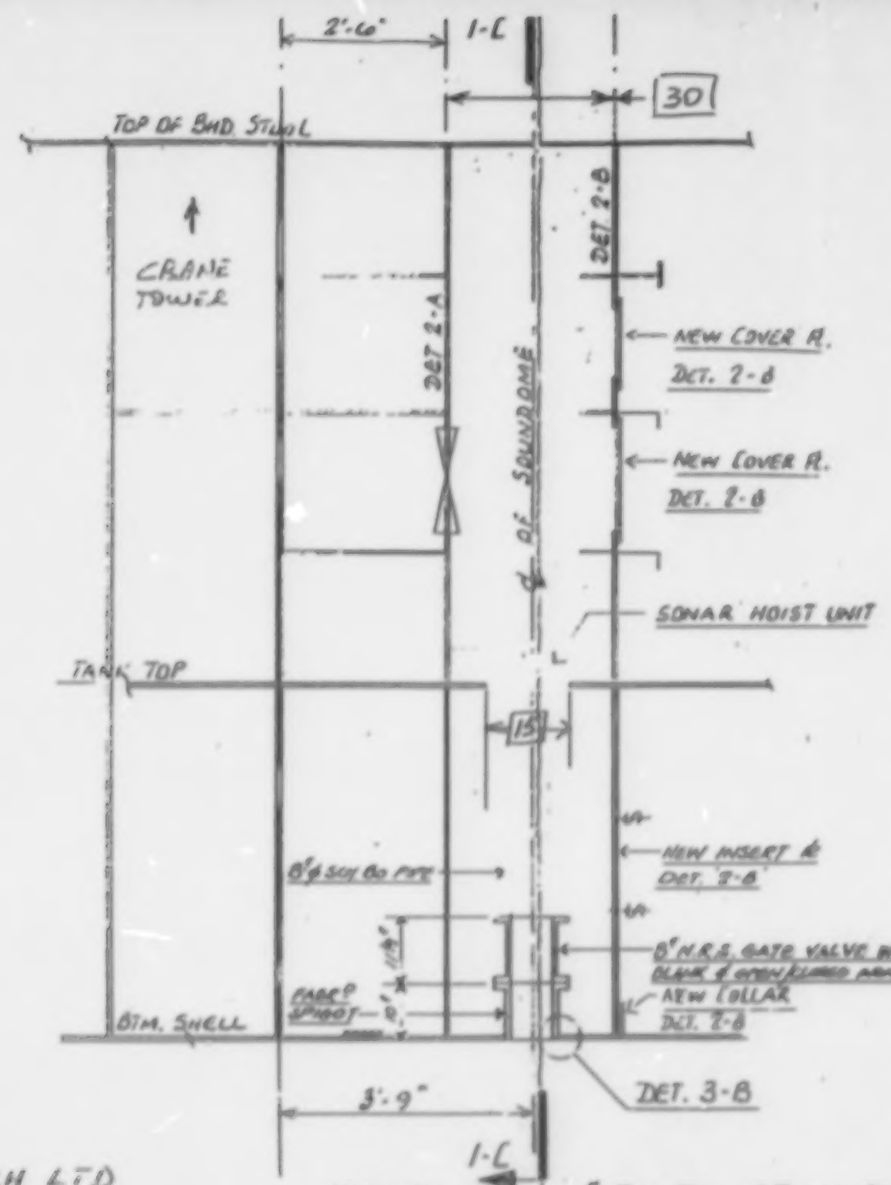
HULL UNIT BLOCK DIAGRAM

C-TECH LTD

SKETCH No: A-1063

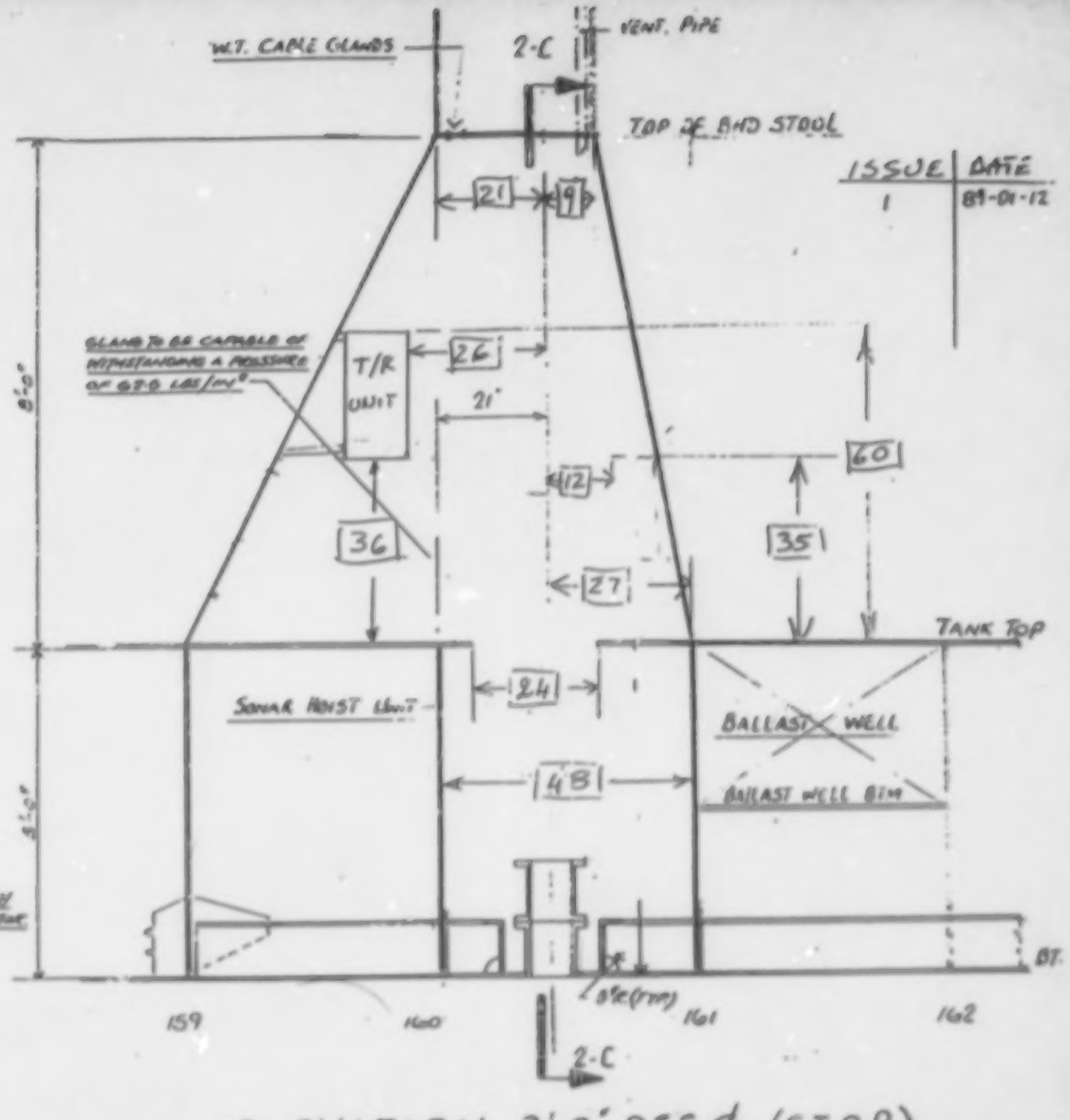
DRAWN: DATE: 89-09-13

ENG APPVL: DATE: 89-09-13




## SECTION 12" FWD FR160

LOOKING FORWARD




## ELEVATION 3'-9" OFF ℄ (STB°)

LOOKING INBOARD

DRG. No. 533-DS/1-H73 Rev

## DETAIL 1-C

SONAR TUBE (STB° ONL

FOR: MILLER DRY DOCKS

□ = ESTIMATED DIMENSIONS IN INCHES

C-TECH LTD

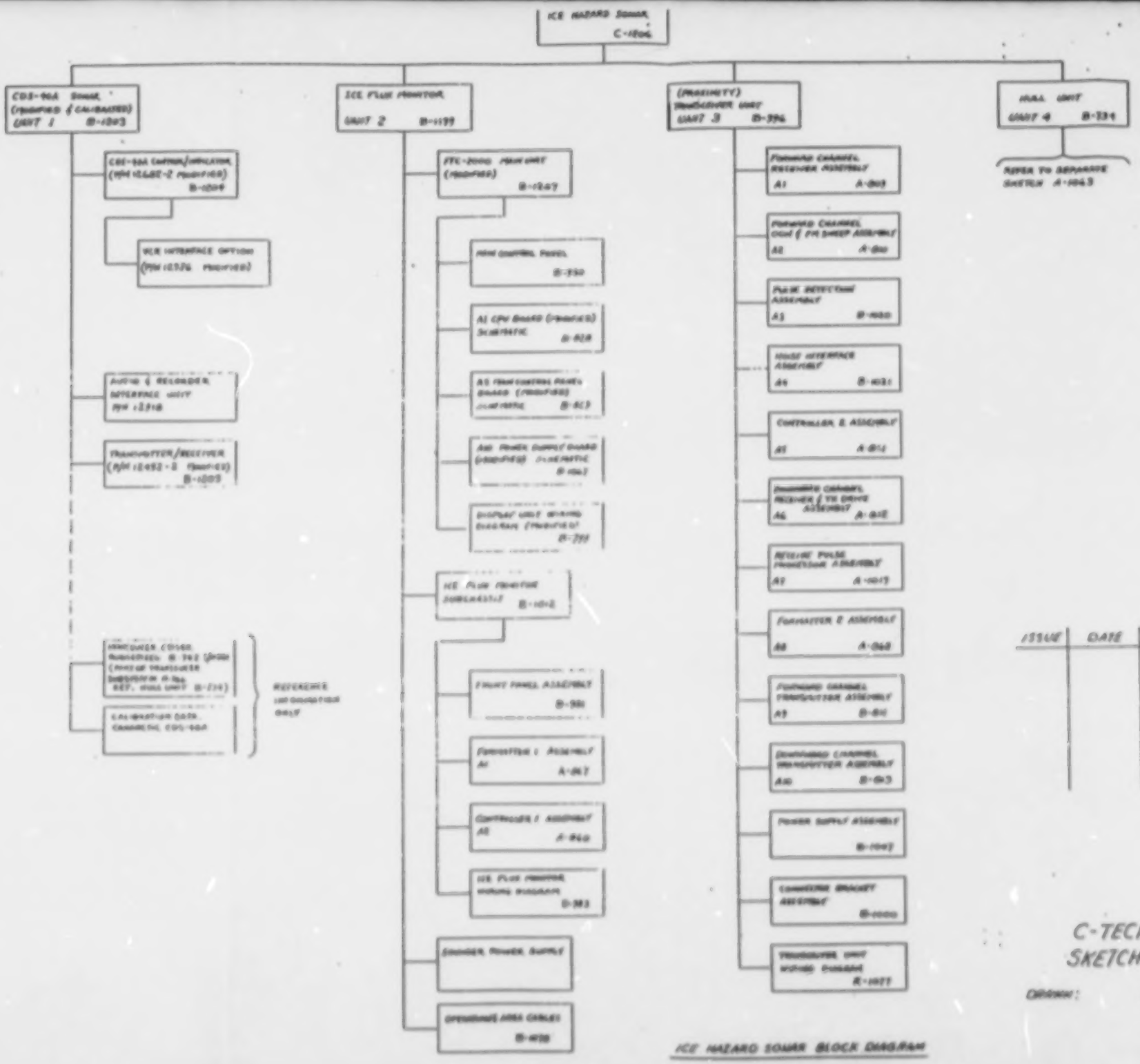
SKETCH No: B-770

DRAWN: [illegible] 12 JAN. '89

ENG. APPVL: [illegible]

## DETAIL 2-C

SONAR COMPARTMENT

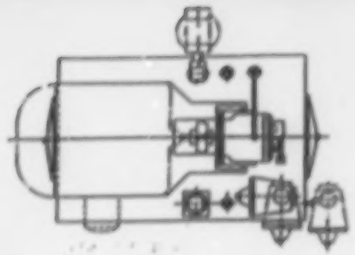

ICE HAZARD SONAR
C-1206
CDS-90A SONAR (TRANSMITTER & CALIBRATED) UNIT 1 B-1093
ICE FLUX MONITOR UNIT 2 B-1199
(PROXIMITY) TRANSCEIVER UNIT UNIT 3 B-396
HULL UNIT UNIT 4 B-334
REFER TO SEPARATE SKETCH A-1043
CDS-90A CONTROL/DISPLAY (WITH 10682-2 MODIFIED) B-1219
VCR INTERFACE OPTION (WITH 10576 MODIFIED)
AUDIO & RECORDER INTERFACE UNIT WITH 13918
TRANSMITTER/RECEIVER (WITH 10652-1 MODIFIED) B-1203
HYDROPHONE COVER NUMBERED 0 TO 3 (FROM TRANSDUCER SUBASSEMBLY A-104 REF. HULL UNIT B-334)
CALIBRATION DATA CARD FOR CDS-90A
REFERENCE ICE DETECTOR UNIT
ITC-2000 MAIN UNIT (MODIFIED) B-1207
MAIN CONTROL PANEL B-350
A1 CPU BOARD (MODIFIED) SCHEMATIC B-828
A2 TRANSMITTER POWER BOARD (MODIFIED) SCHEMATIC B-823
A30 POWER SUPPLY BOARD (MODIFIED) SCHEMATIC B-1063
DISPLAY UNIT WIRING DIAGRAM (MODIFIED) B-799
ICE FLUX MONITOR SUBASSEMBLY B-1042
FRONT PANEL ASSEMBLY B-351
FORMATTER I ASSEMBLY A1 A-847
CONTROLLER I ASSEMBLY A2 A-849
ICE FLUX MONITOR WIRING DIAGRAM B-383
SOUNDER POWER SUPPLY
OPERATING AREA CABLES B-928
FORWARD CHANNEL RECEIVER ASSEMBLY A1 A-869
FORWARD CHANNEL CONT & DR SHEEP ASSEMBLY A2 A-866
PULSE DETECTOR ASSEMBLY A3 B-1030
HOST INTERFACE ASSEMBLY A4 B-1031
CONTROLLER II ASSEMBLY A5 A-814
DOWNWARD CHANNEL RECEIVER & TX DRIVE ASSEMBLY A6 A-812
RECEIVE PULSE PROCESSOR ASSEMBLY A7 A-1015
FORMATTER II ASSEMBLY A8 A-868
FORWARD CHANNEL TRANSMITTER ASSEMBLY A9 B-811
DOWNWARD CHANNEL TRANSMITTER ASSEMBLY A10 B-813
POWER SUPPLY ASSEMBLY B-1041
CONNECTOR BRACKET ASSEMBLY B-1000
TRANSDUCER UNIT WITHIN CHASSIS A-1077

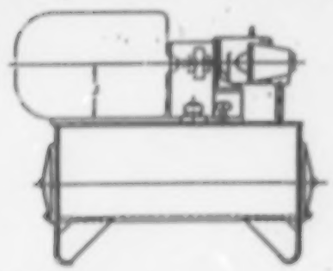
ICE HAZARD SONAR BLOCK DIAGRAM

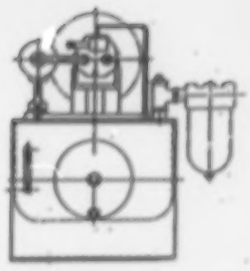
| ISSUE | DATE | APPROVED |
|---|---|---|
| | | |

C-TECH LTD
SKETCH NO. C-1206

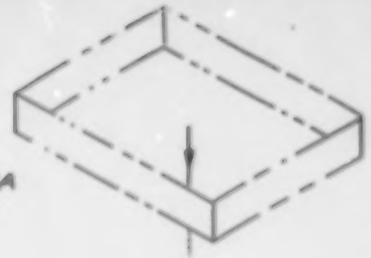
DRAWN: DATE:





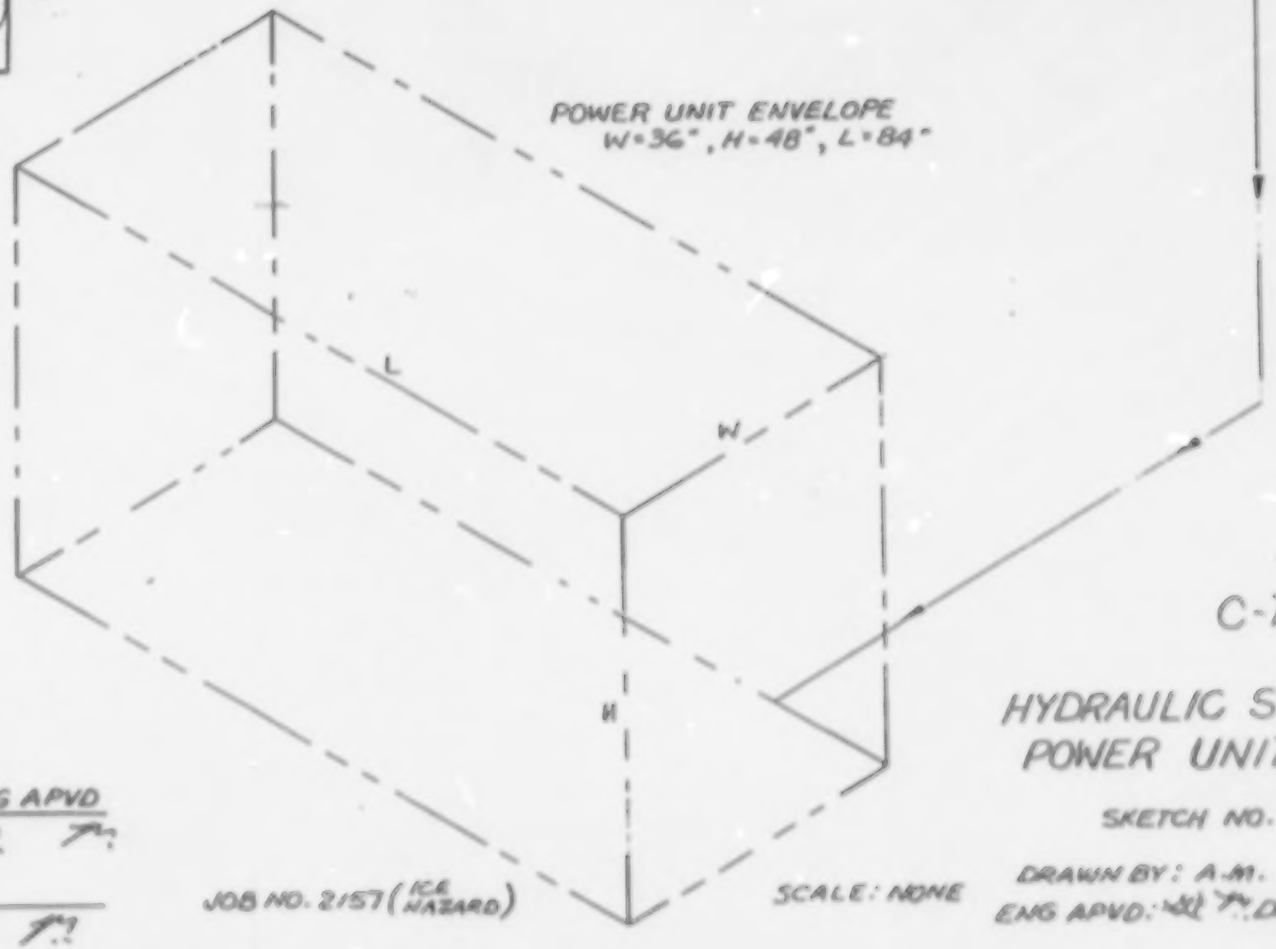


POWER UNIT SHOWN IS TO BE USED FOR REFERENCE ONLY
IT DOES NOT REPRESENT THE FINAL CONFIGURATION



ACCESS AREA
20"X27"

FLOOR TO CEILING HEIGHT = 84"




NOTES:
1. TANK CAPACITY - 150 US GALLONS
2. ELECTRIC MOTOR - 20 HP 360 VAC 60 Hz
   1200 RPM DOUBLE SHAFT EXTENSION
3. PUMPS, FILTERS AND GAGES
   a) PUMP - FIXED CAPACITY
      "VICKERS" 50V72-A-1-A-10 132
      FILTER - PUMP OUTPUT "VICKERS" OFRT-120-S-10
      (400 PSI) ELE.- 737391
      PUMP INPUT "VICKERS" OF3-20 3RV-3
      GAGE - LOW PRESSURE
   b) PUMP - VARIABLE CAPACITY
      "VICKERS" PVBG-F-R-S-WY20CCGL10
      FILTER - PUMP OUTPUT "VICKERS" OFP-15-S-10
      (2000 PSI) ELE.-926412
      PUMP INPUT "VICKERS" OF3-20 3RV-3
      GAGE - HIGH PRESSURE
4. POWER UNIT MUST PASS THROUGH THE ACCESS AREA SHOWN WITH MINIMUM DISASSEMBLY

| ISSUE | DESCRIPTION | DATE | ENG APVD |
|---|---|---|---|
| 1 | APPROVED FOR MATERIAL PROCUREMENT - NOT TO BE USED FOR INSTALLATION | 89-09-05 | ALL |
| 2 | | 89-10-12 | ALL |

JOB NO. 2157 (ICE HAZARD)

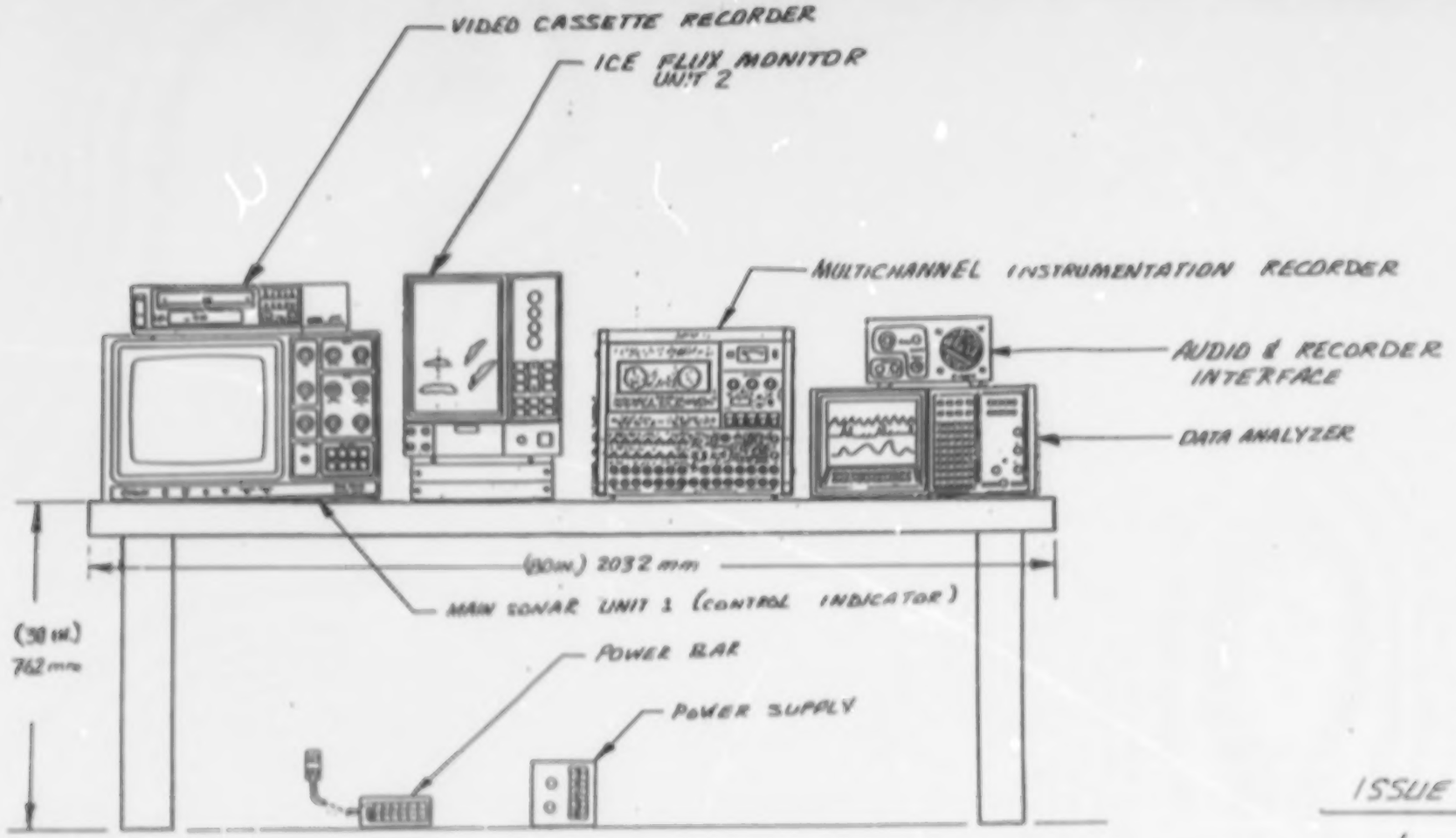
SCALE: NONE

C-TECH LTD

HYDRAULIC SYSTEM
POWER UNIT

SKETCH NO. B-1051

DRAWN BY: A.M. DATE: 5 SEPT
ENG APVD: ALL DATE: 89-09-05




# ICE HAZARD DETECTION SONAR

## OPERATIONS AREA EQUIPMENT INSTALLATION DRAWING

(PREFERRED VERSION)

| ISSUE | DATE |
|---|---|
| 1 | 15-12-88 |
| 2 | |

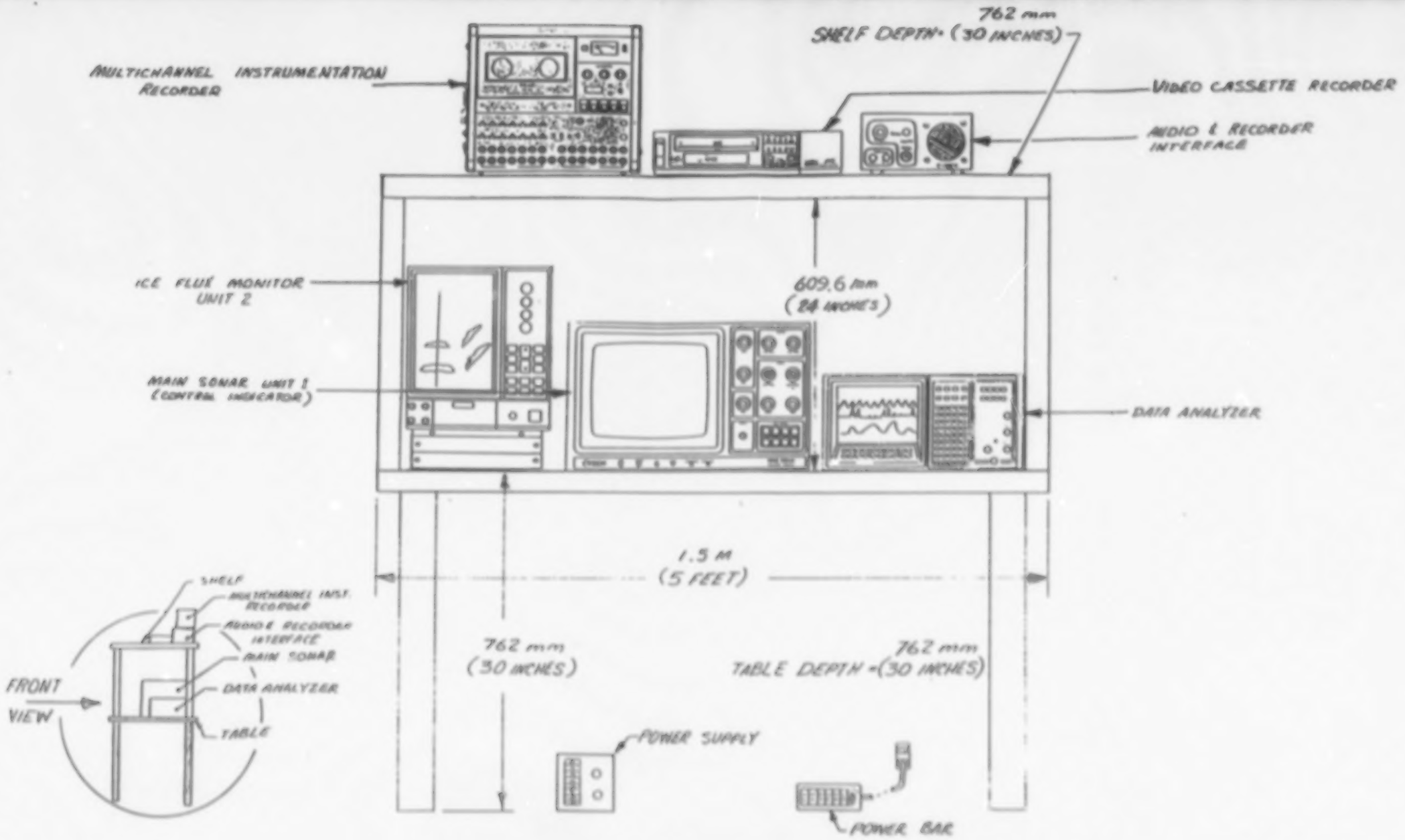
C-TECH LTD.

SKETCH NO. B-725

DRAWN: JDP DATE: 15 Dec '88

ENG APPVD: RWB DATE: 15 DEC '88

SHEET 1 OF 6

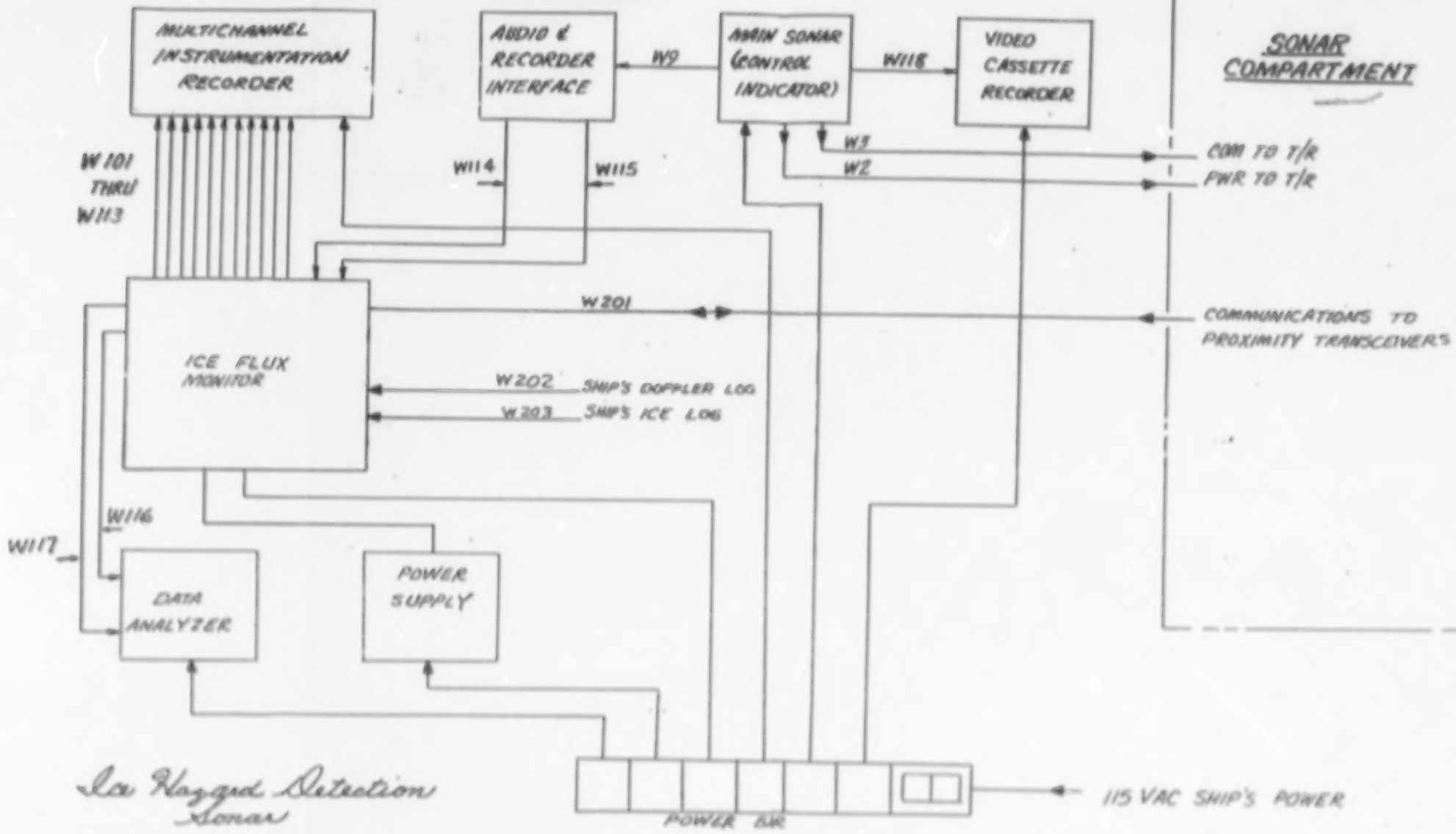



ICE HAZARD DETECTION SONAR

OPERATIONS AREA EQUIPMENT INSTALLATION DRAWING (ALTERNATE VERSION)

C-TECH LTD.
SKETCH NO. B-72
SHEET 2 OF 6

## OPERATIONS AREA




EQUIPMENT INTERCONNECTION

C-TECH LTD.
SKETCH NO. B-725

SH 3 OF 6

| OPERATIONS AREA EQUIPMENT | HEIGTH IN. | HEIGTH mm | WIDTH IN. | WIDTH mm | DEPTH IN. | DEPTH mm | REMARKS |
|---|---|---|---|---|---|---|---|
| MAIN SONAR (CONTROL INDICATOR) | 13.5 | 343 | 22.8 | 577.1 | 16.1 | 409 | |
| VIDEO CASSETTE RECORDER | 3.75 | 95 | 17.12 | 435 | 14.8 | 376 | |
| AUDIO & RECORDER INTERFACE UNIT | 5.0 | 127 | 10.0 | 254 | 8.0 | 203.2 | |
| ICE FLUX MONITOR | 19.0 | 482.6 | 13.19 | 335 | 18.89 | 480 | |
| DATA ANALYZER | 13.0 | 330.2 | 17.0 | 431.8 | 17.0 | 431.8 | TYPICAL } "DATA PRECISION" DATA 6000 |
| POWER SUPPLY | 5.0 | 127 | 5.0 | 127 | | | TYPICAL } "RTE POWER/MATE" SU-UNI-300CV |
| MULTICHANNEL INSTRUMENTATION RECORDER | 12.6 | 320 | 15.0 | 381 | 7.56 | 192 | TYPICAL } (1050) DEPENDS ON RECORDER SELECTED |
| | 6.1 | 155 | 19.0 | 481 | 24.4 | 619 | TYPICAL } (STORE 1600) |
| POWER BAR, 6 OUTLET | 2.5 | 63.5 | 18.5 | 469.1 | 2 | 50.8 | |

EQUIPMENT DIMENSIONS

C-TECH LTD.
SKETCH NO. B-729

SHEET 4 OF 6

| CABLE IDENTIFICATION | PART NUMBER | CONNECTOR STYLE, O.D. (in.) mm | CONNECTOR STYLE O.D. (in.) mm | LENGTH (ft) METRES O.D. (in.) mm | REMARKS |
|---|---|---|---|---|---|
| AUDIO CABLE W9 | 12499 | 206044-1 "AMP" (1.315) 33.4 o.d. | 206044-1 "AMP" (1.315) 33.4 O.D. | 55ft "ALPHA" 7PR #22 SHIELDED (8) 2.4 LENGTH (.33) 9.9 O.D. | MAIN SONAR (C1) TO AUDIO & RECORDER INTERFACE |
| SIGNAL CLOCK (2 IDENTICAL CABLES) | W114 W115 | 36775 BNC "AMP" (.562) 14.3 O.D. | 36775 BNC "AMP" (.562) 14.3 O.D. | RG-58 (50Ω) 8259 "BELDEN" (.195) 4.95 O.D. LENGTH - (8) 2.4 | AUDIO & RECORDER INTERFACE TO ICE FLUX MONITOR. |
| DATA ANALYZER CHANNEL 1, CHANNEL 2 (2 IDENTICAL CABLES) | W116 W117 | 36775 BNC "AMP" (.562) 14.3 O.D. | 36775 BNC "AMP" (.562) 14.3 O.D. | RG-58 (50Ω) 8259 "BELDEN" (.195) 4.95 O.D. LENGTH - (8) 2.4 | ICE FLUX MONITOR TO DATA ANALYZER |
| RECORDER CHANNEL 1 THRU CHANNEL 13 (13 IDENTICAL CABLES) | W101 THRU W113 | 36775 BNC "AMP" (.562) 14.3 O.D. | 36775 BNC "AMP" (.562) 14.3 O.D. | RG-58 (50Ω) 8259 "BELDEN" (.195) 4.95 O.D. LENGTH - (8) 2.4 | ICE FLUX MONITOR TO MULTICHANNEL INSTRUMENTATION RECORDER |
| VIDEO CABLE | W118 | 3558-5 "SWITH-CRAFT" | "SCART" | RG-59 (75Ω) 8241 "BELDEN" (.242) 6.15 O.D. LENGTH - (8) 2.4 | MAIN SONAR (C1) TO VIDEO CASSETTE RECORDER |
| POWER CORDS (ALL PART OF EQUIPMENTS) | | PART OF EQUIPMENT | PART OF EQUIPMENT | PART OF EQUIPMENT | MAIN SONAR (C1), VCR, POWER SUPPY, DATA ANALYZER, MULTICHANNEL INSTRUMENTATION RECORDER TO POWER BAR |
| | | | | | |

TABLE 1 OPERATIONS AREA EQUIPMENT LOCAL INTERCONNECTING CABLING

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SKETCH NO. 8-729

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| CABLE IDENTIFICATION | PART NUMBER | TERMINATION 1 CONNECTOR STYLE O.D. (in.) mm | TERMINATION 2 CONNECTOR STYLE O.D. (in.) mm | CABLE TYPE LENGTH (ft) METRES O.D. (in.) mm | REMARKS |
|---|---|---|---|---|---|
| POWER CABLE W2 | 12934 (MANUFACTURED) | 206037-2 "AMP" (1.315) 33.4 O.D. | 206426-1 "AMP" (1.315) 33.4 O.D. | 14/3 NEOPRENE JACKET, 600V, 75% 50 (34) 13 O.D. | MAIN SONAR (C.I.) (OPERATIONS AREA) TO T/R (SONAR COMPARTMENT) (LENGTH TBD FROM SHIP'S DATA) |
| CONTROL CABLE W3 | 12453 (MANUFACTURED) | 206037-1 "AMP" (1.315) 33.4 O.D. | 206037-1 "AMP" (1.315) 33.4 O.D. | 5571 "ALPHA" TYPE #22, SHIELDED (.39) 9.9 O.D. | MAIN SONAR (C.I.) (OPERATIONS AREA) TO T/R (SONAR COMPARTMENT) (LENGTH TBD FROM SHIP'S DATA) |
| FIBER OPTIC COMMUNICATIONS CABLE | W201 | 91710-140-1P "TEL" SMA CONN. (.310) 7.9 O.D. (4 PCS./END) | 91710-140-1P "TEL" SMA CONN. (.310) 7.9 O.D. (4 PCS./END) | "BELDEN" 226614 100 m / 140 m 4 FIBRE F.O. CABLE (.315) 8 O.D. | ICE FLUX MONITOR (OPERATIONS AREA) TO PROXIMITY TRANSCEIVER (SONAR COMPARTMENT) (LENGTH TBD FROM SHIP'S DATA) |
| | | | | | |
| DOPPLER LOG CABLE | W202 | 206037-1 "AMP" (1.315) 33.4 O.D. | | | DOPPLER LOG TO ICE FLUX MONITOR |
| ICE LOG CABLE | W203 | 206037-1 "AMP" (1.315) 33.4 O.D. | | | ICE LOG TO ICE FLUX MONITOR |
| | | | | | |
| | | | | | |

TABLE 2 SHIP'S INTERCONNECTING CABLING

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# APPENDIX H

## ICE HAZARD SONAR DESIGN STATUS

## APPENDIX H

## ICE HAZARD SONAR DESIGN STATUS

| TASK DESCRIPTION | STATUS |
|---|---|
| **1.0 SYSTEM DESIGN** | Complete |
| **2.0 DESIGN SPECIFICATIONS** | Complete |
| **3.0 DETAIL DESIGN** | |
| **3.1 Primary Sonar Software** | Complete |
| **3.2 Proximity Sounder Subsystem** | |
| Forward Looking Sounder | Complete |
| Downward Looking Sounder | Complete |
| Alarm Processor | Complete |
| Data Collection Interface | Complete |
| Ice Flux Monitor | Complete |
| Fibre Optic Link | Complete |
| **3.3 Transducer Assembly** | |
| Primary Transducer Modification | Complete |
| Forward Looking Transducer | Complete |
| Downward Looking Transducer | Complete |
| **3.4 Mechanical Subsystem** | |
| Retraction Mechanism | Complete |
| Hydraulic Power Unit | Components selected |
| Hydraulic Valve Block | Components selected |
| Sea Chest | Complete |
| Air Supply | Complete |
| Retraction Mechanism Controller | Specification Complete |

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## ICE HAZARD SONAR DESIGN STATUS (continued)

| TASK DESCRIPTION | STATUS |
|---|---|
| **4.0 CONSTRUCTION** | |
| **4.1 Proximity Sounder Subsystem** | |
| Forward Looking Sounder | 90% complete |
| Downward Looking Sounder | 90% complete |
| Alarm Processor | 70% complete |
| Ice Flux Monitor | Complete |
| Fibre Optic Link | Complete |
| **4.2 Transducer Assembly** | |
| Primary Transducer Modification | 05% complete |
| Forward Looking Transducer | 50% complete |
| Downward Looking Transducer | 50% complete |
| **4.3 Mechanical Subsystem** - Assembly not started | |
| Retraction Mechanism | |
| Hydraulic Power Unit | |
| Hydraulic Valve Block | |
| Sea Chest | |
| Air Supply | |
| Retraction Mechanism Controller | |

# APPENDIX I

## PROJECTED TASKS AND COSTS FOR PROGRAM COMPLETION

## APPENDIX I - PROJECTED TASKS AND COSTS FOR PROGRAM COMPLETION

| PHASE/TASK | HOURS | | | | |
|---|---|---|---|---|---|
| | MGT. | ENG. | TECH. | TEST ENG. | DRAFT |
| 1.0 PROJECT MANAGEMENT | 100 | | | | |
| | | | | | |
| 2.0 DESIGN | | | | | |
| Retraction Mech. | | 40 | | | |
| Test Simulator | | 40 | | | 24 |
| Mech. Fixturing | | 40 | | | |
| | | | | | |
| 3.0 CONSTRUCTION | | | | | |
| Proximity Subsystem | | 8 | 24 | | 48 |
| Test Simulator | | | 40 | | |
| Transducer Assembly | | 18 | | | |
| Retraction Mech. | | 80 | | | |
| RAM Controller | | 32 | | | |
| Mech. Fixturing | | 80 | | | 80 |
| | | | | | |
| 4.0 INTEGRATION | | | | | |
| Electronics | | 120 | 160 | | |
| Mechanical | | 80 | | | |
| System | | 40 | 40 | | |
| | | | | | |
| 5.0 TEST | | | | | |
| In Plant Test Plan | | 80 | | | |
| CDS-40 Sonar Cal. | | | | 32 | |
| Sounder Advocare | | 8 | | 8 | |
| Electronics | | 80 | 80 | | |
| RAM Controller | | 20 | 40 | | |
| Mechanical | | 40 | 40 | | |
| System | | 40 | 40 | | |

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| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| PHASE/TASK | HOURS | | | | |
| | MGT. | ENG. | TECH. | TEST ENG. | DRAFT |
| 6.0 INSTALLATION | | 160 | 160 | | |
| | | | | | |
| 7.0 SEA TRIAL | | | | | |
| Sea Trial Plan | | 80 | | | |
| Sea Trial | | 80 | 80 | | |
| | | | | | |
| 8.0 ANALYSIS | | 400 | 40 | | 20 |
| | | | | | |
| 9.0 FINAL REPORT | | 80 | | | 20 |
| | | | | | |
| TOTALS | 120 | 1016 | 744 | 40 | 782 |
| | | | | | |
| RATE/HR | @ 55 | @ 55 | @ 55 | @ 140 | @ 85 |
| $000 | 6.6 | 55.9 | 40.9 | 5.6 | 6.7 |

| | $000 |
|---|---|
| TOTAL DESIGN LABOUR - CTL | 143.6 |
| - SUB | 25.0 |
| MATERIAL (INCL. CONTROLLER) | 125.0 |
| MANUFACTURING LABOUR | 25.0 |
| | 318.6 |

# APPENDIX J

## PROPOSED TEST PROGRAM

# APPENDIX J - PROJECTED TEST PROGRAM

## 1.0 DEVELOPMENT TEST PLAN, ICE HAZARD DETECTION SONAR SUBSYSTEM

### 1.1 SCOPE

This plan identifies and outlines the major development test requirements of the subject subsystem to assure compliance with the following applicable documents:

a) CTL Report No. 1075, "System Design Specification for a Ruggedized Transducer Subsystem for Ice Hazard Detection Sonar"

b) CTL Report No. 1069, "Statement of Work - Retraction Mechanism Subsystem for Ice Hazard Detection Sonar"

c) CTL Sketch No. A-1098, "Retraction Mechanism Controller for Ice Hazard Detection Sonar"

### 1.2 BREADBOARD AND FIRMWARE MODULE TESTS

#### 1.2.1 Transceivers

Verify performance for the following blocks:

Forward Receiver Front End
Downward Receiver Front End
TVG Control
Own Doppler Nullifier (forward channel only)
I.F. Channel
FM Sweep Generator (forward channel only)
Forward Transmitter Tuning and Matching
Downward Transmitter Tuning and Matching

1.2.2 Alarm Signal Processors

Verify performance for the following blocks:

RX Pulse Processor (forward channel only)
Fixed Echo Suppression & Reference Memories (forward channel only)
Range Gate
M-out-of-N Discriminator
Ship's Log Interface
Alarm Interface
Transmit Pulse Processor

1.2.3 Proximity Sounder Main Unit

Verify performance for the Source Selector modification.

1.2.4 Main Sonar Software

Verify functionality for the Main Sonar Software modification.

1.2.5 Main Transducer

Verify performance for the following block:

Element Transducer

1.2.6 Proximity Transducers

Verify performance for the following blocks:

Piezoelectric ceramics
Array in air
Array in water

1.3.0 EXTERNALLY SOURCED SUB-ASSEMBLY TESTS

1.3.1 Proximity Sounder Power Supply

Verify operational compatibility with the proximity sounder main unit.

1.3.2 Acoustic Data Collection Recorder

Verify functionality and compatibility with the performance requirements.

1.3.3 Retraction System Controller

Verify functionality and compatibility with the performance requirements of Sketch A-1098, "Retraction Mechanism Controller for Ice Hazard Detection Sonar".

1.3.4 Retraction System

Perform functional testing to verify the following:

a) Position repeatability
b) Speed - extending and retracting (with simulated drag applied)
c) Position feedback accuracy
d) Load capacity
e) Cycling effect for a 24 hour duration
f) Operation at low temperature (-3° C)
g) Water seal integrity

Where practical, test equipment will be used to simulate alarm processor I/O functions.

1.4.0 MAJOR COMPONENT READINESS TESTING

1.4.1 Proximity Sounders

Perform functional testing to verify the intra-unit functionality of the Proximity Sounder/Main Unit combination within the limits set by its high interactivity with the Alarm Processor Block. Where practical, test equipment will be used to simulate Alarm Processor Functions.

1.4.2 Alarm Signal Processor

Perform functional testing to verify the intra-unit functionality of the Alarm Signal Processor within the limits set by its high interactivity with the Proximity Sounder and the Ship's Log. Where practical, test equipment will be used to simulate these functions on a test-by-test basis.

1.4.3 Proximity Sounder Controls

Characterize and record the transfer functions of the sounder channels, TVG cont[illegible] and sensitivity and/or alarm threshold controls for use in the data analysis phase.

1.4.4 Proximity Transducers

Measure and record the transmitting response, receiving response, bandwidth and impedance of each transducer.

Plot the horizontal and vertical transmitting and receiving beam patterns.

1.4.5 Main Transducer

Measure and record the transmitting response, receiving response, and ring impedances.

1.5.0 INTEGRATION TESTING

Perform integration testing to ensure the compatibility of the interactive functional blocks in the following areas:

1.5.1 Proximity Sounders to Proximity Transducers

Verify the impedance matching, transmitter loading and power, and receiver noise levels.

1.5.2 Proximity Sounders to Alarm Signal Processor

Verify the following interfaces:

a) Transmit Pulse Processor/FM Sweep Generator
b) Transmit Pulse Processor/TVG Controls
c) Transmit Pulse Processor/downward channel transmitter
d) IF Channel/Receive Pulse Processor, forward channel
e) IF Channel/Range Gate, downward channel
f) Ship's Log Interface/Own Doppler Nullifier
g) Acoustic Data and Control interfaces for Acoustic Data Recorder

Set the alarm thresholds for the specified P(FA) using simulated signals.

1.5.3 Alarm Signal Processor to Ship's Log

It is expected that simulation of ship's log data will be required based on supplied ship's log interface and format specification data.

1.5.4 Alarm Signal Processor to Retraction System Controller

Verify the compatibility of the Retraction System Controller with the Alarm Signal Processor position request signals.

Verify the compatibility of the Alarm Signal Processor with the Retraction System Controller status feedback signals.

1.5.5 Alarm Signal Processor to Main Sonar

Verify the compatibility of the Alarm Signal Processor with the Main Sonar Raise/Lower commands.

Verify the compatibility of the Main Sonar with the Alarm Signal Processor status feedback signals.

1.5.6 Alarm Signal Processor to Acoustic Data Collection Recorder

Verify the compatibility of acoustic data and control signal interfaces with the Acoustic Data Collection Recorder and Monitor Oscilloscope.

1.5.7 Retraction System Controller to Retraction System

Verify the compatibility of the Retraction System Controller with the Retraction System.

1.6.0 IN-PLANT SYSTEM TEST

1.6.1 Electroacoustic, Proximity Sounders

Measure the source level for both sounders.

Measure the detection sensitivity for the receiver/alarm interface design threshold.

Verify the alarm functionality with known target levels.

1.6.2 Electroacoustic, Main Sonar

Characterize the main sonar/transducer combination and record results to update the information in C-Tech Report No. 851, "Calibration Data, Canarctic CDS-40A (Refurbished System)".

1.6.3 Main Sonar, Proximity Sounder, and Alarm Signal Processor to Retraction System Controller & Retraction System

Perform final testing in water to verify retraction system response to alarm cycling, using passive or active targets.

## 2.0 SEA TRIALS

### 2.1 Objectives.

The principal objective of the Test Program as outlined in Table 1 is:

i) To demonstrate the "Seek and Hide" concept with actual hardware in an Arctic sea environment. In addition, the test will be used to show that the approach is a cost effective solution for reliable near range ice detection.

As a secondary objective, the Test Program will collect data to support the engineering of an operational ice detection sonar.

The Program will include steps to:

ii) Obtain and analyze data which would result in a better understanding of the ice/water physical environment of the transducer and of the transducer operation.

iii) Obtain and analyze a modest amount of acoustic data which would allow qualification of the acoustic operating environment of the transducer, both for the ice pieces detector and for the primary transducer.

Taken together (ii) and (iii) will explain and generalize the conclusions reached under (i). Whereas objective (i) is mainly of a go/no-go nature, (ii) and (iii) will promote understanding, generalization and, finally, progressive technology.

Finally, note that the ship baselined for the test is the M.V. Arctic, as it has the right draught and that the CDS-40A, the sonar adopted for the proof of concept tests, is already installed on board. The tests description, however, could apply with a few modifications to a ship of alternate choice.

## 2.2 Test Program.

In order to accomplish the objectives set forth, it is estimated that a test program of a total of some six dedicated ship's days is needed. These days will be used most efficiently if they are taken during a period of say, seven to nine days total. This might be possible, e.g., if part of the tests were carried out prior to entering an Arctic harbour, and the balance upon departure.

Table 1 is an outline of activities to take place during the tests. A detailed test plan will be generated at the appropriate time as part of the work program. Note that Table 1 proposes a progressive increase in the difficulty of operation, with appropriate data collecting, so that in the event of system failure all possible records are collected.

The work program will include acoustic measurements of near-field noise and reverberation levels, target strength and frequency of ice pieces as seen by the proximity sounders and main sonar. Data to support assessment of the functionality, operating characteristics and reliability of the ruggedized subsystem will also be collected.

## 2.3 Hardware Installation.

The complete installation of the equipment will be performed by C-Tech once any necessary fitting of the ship is completed. In this discussion, it has been assumed that the installation will be on the M.V. Arctic using a CDS-40A OMNI Sonar.

## 2.4 Confirmation of Performance.

The trial program has been set up to demonstrate the reliable performance of the hull system and transducer portion of the ice detection sonar. The quantitative evaluation will be based on the availability of the system, the time to repair in the event of damage and the analysis of the acoustic data on the ice flux. This analysis will provide the data necessary to substantiate the ice-environment model permitting, at a later date, the complete engineering design of a fully operational ice detection sonar.

TEST PROGRAM OUTLINE

| NO. | ACTIVITY | DEDICATED SHIP TIIME | NOTES |
|---|---|---|---|
| 1 | Factory test of Seek and Hide hull unit includinig test of retraction system and acoustic test of main sonar transducer and proximity transducers. | 0 | Transducer acoustic tests will be performed in C-Tech's Underwater Test Facility (UWTF). |
| 2 | Checkout of all systems in harbour and in open sea. Static check, dynamic check, acoustic check (false alarms, etc.) | 0 | |
| 3 | Checkout of all systems in Arctic environment with ship stationary in ice. Test with simulated target. | 1/4 day check<br>1/4 day adjustment | |
| 4 | Operation at dead slow (1-2 knots) in thin ice as available. False alarms, manual retraction tests, test with simulated ice target. | 1/4 day check<br>1/4 day adjustment<br>3/4 day data collection | No real ice pieces expected. |
| 5 | Operation dead slow thicker ice as possible (as above). | 3/4 day as above | No real ice pieces expected. |
| 6 | Operation at 3-4 knots (slow) in thin ice. | 3/4 day as above | Probably some ice pieces. |
| 7 | Operation at 3-4 knots (slow) in thicker ice. | 3/4 day | Probably more ice pieces. |
| 8-9 | Operatioin in thicker ice and greater speed; small ridges. | 3/4 day | As resulting from previous tests. |
| 10 | Repairs and substitutions. | 1 day | Dummy transducer head will be used some of the time; system designed for easy substitution. |
| 11 | Spare | 1 day | |

Note that the total time necessary might be less if fewer tests are to be performed or if sufficient time for adjustments, repairs, etc. is available between the tests.